UPPER MUD PINE CREEK WATERSHED DIAGNOSTIC STUDY
Benton County, Indiana

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UPPER MUD PINE CREEK
WATERSHED DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

The Upper Mud Pine Creek Diagnostic Study is a comprehensive examination of Mud Pine Creek, Seamons Ditch and Goose Creek and their surrounding watersheds. In 2001, with funding from the Indiana Department of Natural Resources Lake and River Enhancement (L.A.R.E.) Program, the Elkhart County Soil and Water Conservation District hired the team of Indiana University and J.F. New & Associates to conduct the study. The purpose of the study was to describe the historical and existing condition of the watersheds, identify potential problems, and make prioritized recommendations addressing these issues. It included a review of historical studies, several mapping exercises, an aerial and windshield tour of the watersheds, an assessment of chemical, biological and physical stream health, and interviews with watershed residents and local and state agencies.

The Upper Mud Pine Creek Watershed addressed in this study encompasses 41,797 acres of Benton and Warren Counties from Fowler, Indiana south to County Road 900 South (Benton-Warren County line). Historically, much of the watershed was tall grass prairie, less than 1% of natural tall grass habitat exists within the watershed today. The watershed is 87% row crop agriculture. All tributary streams sampled will be considered modified warm water habitat due to their primary use as drainage ditches. The soils are predominantly silty clay loam of low erosion potential that are considered prime farmland. Conservation tillage is utilized on 62% of soybean fields and 19% of corn fields.

The study documented water quality concerns regarding ammonia-nitrogen, nitrate-nitrogen and phosphorus as primary chemical pollutants to the waterways. The macroinvertebrate Index of Biotic Integrity (mIBI), an index which utilizes invertebrate community structure to measure water quality, documented a range of moderately impacted (2.0) to just barely unimpaired (6.5). Habitat as assessed using the Qualitative Habitat Evaluation Index (QHEI) was also less than optimal for aquatic life uses at most sites. Water quality samples taken during storm events exceeded state standards for some chemical parameters and for *E. coli* at many sample sites. Historical studies suggest habitat quality improved downstream of the study reach where ditching activities have not occurred.

Approximately 125 land treatment or restoration projects are recommended to reduce soil erosion and improve stream habitat throughout the study area. Priority subwatersheds identified include the Goose Creek Subwatershed followed by the Seamons Ditch Subwatershed. Potential recommended land management treatments in the watershed included: wetland restoration, filter strip installation, buffer zone establishment, bank stabilization, livestock fencing, revegetation of exposed area, and grassed waterway construction. Coordination with the Town of Fowler and the County Drainage Board along with management at the watershed-level and public education and outreach were also recommended.

ACKNOWLEDGEMENTS

This Watershed Study was performed with funding from the Indiana Department of Natural Resources – Division of Soil Conservation and the Elkhart County Soil and Water Conservation District. J.F. New and Associates, Inc. and Indiana University – School of Public and Environmental Affairs documented the historical information available, completed tributary stream sampling for nutrient and sediment loading, and modeled nutrient and sediment loading to major rivers. Neil Deckard currently of the Newton County Natural Resources Conservation Service (NRCS) and Jason Kimbrough of the Benton County SWCD provided initiative and assistance in getting this study completed. Significant contributors to this study included: Todd Davis, Stacey Sobat, and Chuck Bell with the Indiana Department of Environmental Management (IDEM); Jim Lake and Gene Matzat with the Purdue Cooperative Extension Agency; Jill Hoffmann, Jennifer Bratthauer, Deiter Markland, Brant Fisher, Ron Hellmich, and Jed Pearson with the Indiana Department of Natural Resources (IDNR); Julie McLemore of the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS); Jack Steel of the Benton County Surveyor's Office; Alan Leuck with the town of Fowler; Jim Whet with the town of Boswell; Tom Glotzbach, a Benton County SWCD board supervisor; Cedric Durkis of the Benton County Purdue Cooperative Extension Agency; David Whybrew of Key Engineering Group. Authors of this report included William Jones, Melissa Clark, and Nick Haxton at Indiana University and Cornelia Sawatzky, Marianne Giolitto, John Richardson, and Steve Zimmerman at J.F. New and Associates, Inc.

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INTRODUCTION

The Upper Mud Pine Creek Watershed is located south of Fowler in Benton and Warren Counties, Indiana (Figure 1). The watershed drains about 41,797 acres, and encompasses all of three 14-digit watersheds, the Mud Pine Creek Headwaters Watershed (HUC 05120108050010), the Mud Pine Creek-Seamons Ditch Watershed (HUC 05120108050020), and the Mud Pine Creek-Goose Creek Watershed (HUC 05120108050030). The study area lies within Center, Grant, and Oak Grove Townships in Benton County and Pine Township in Warren County. For the purpose of this study, the watershed was further divided into eight smaller subwatersheds (Figure 2).

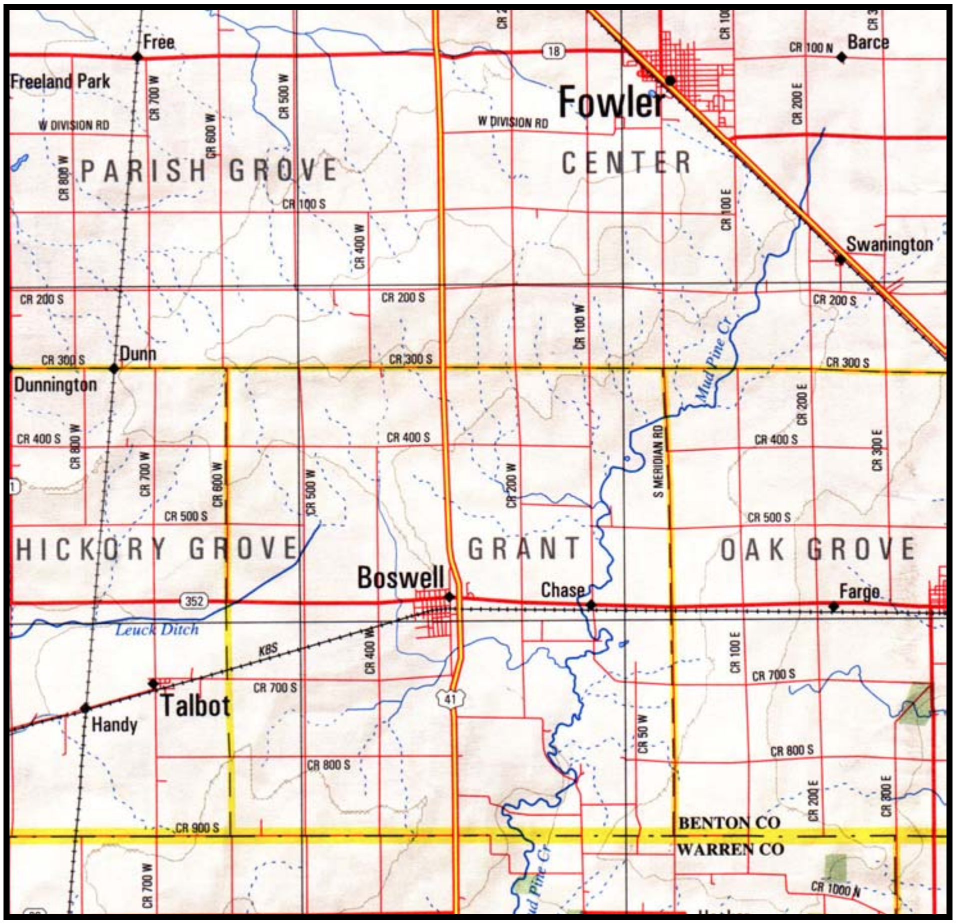

FIGURE 1. Study location map. The scale is 1”=2.5 miles.

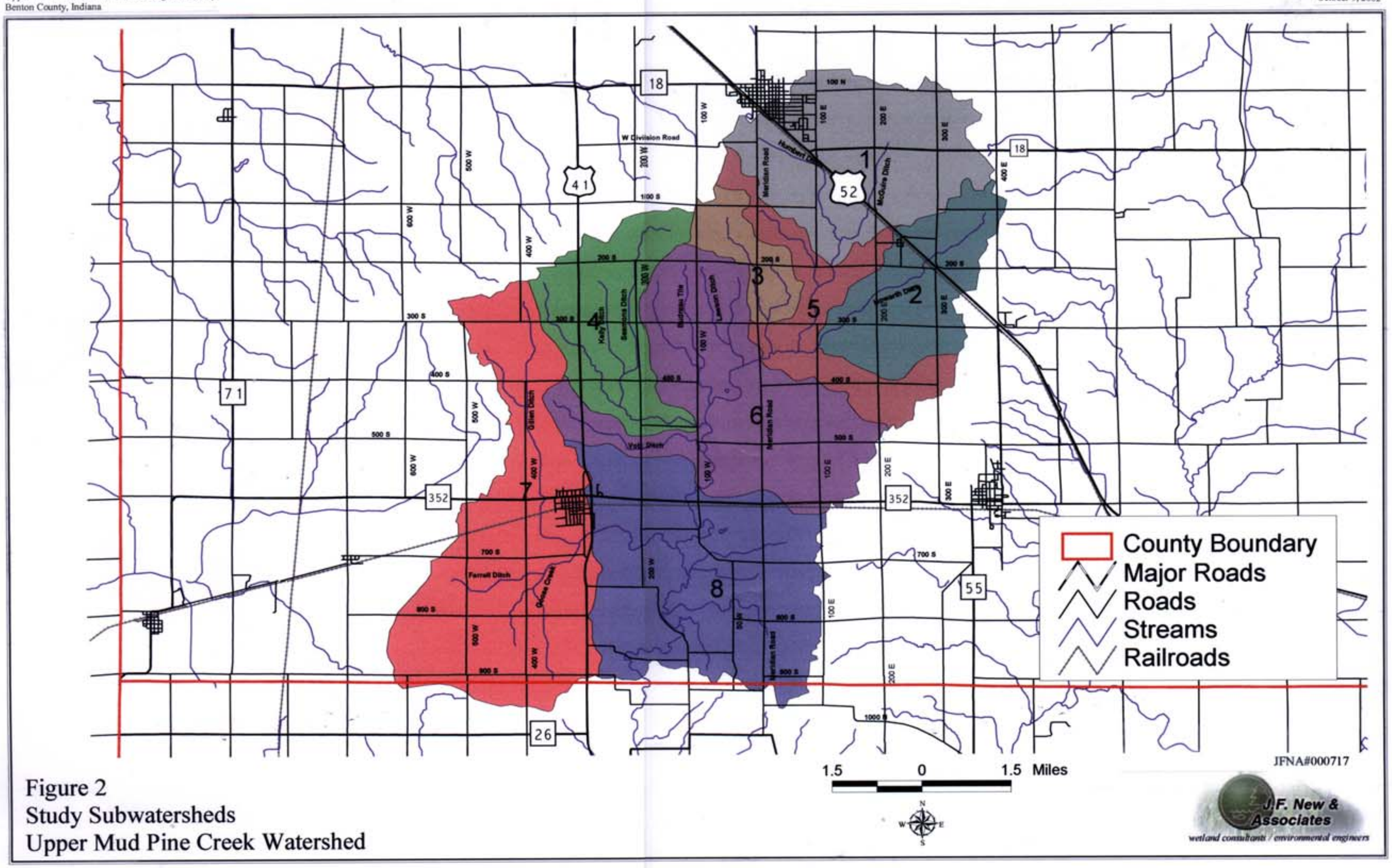

Figure 2
Study Subwatersheds
Upper Mud Pine Creek Watershed

The watershed is part of the 8-digit Middle Wabash-Little Vermillion Watershed HUC 05120108 (Figure 3). Water from Mud Pine Creek discharges into Big Pine Creek southwest of Pine Village in Warren County. Big Pine Creek joins the Wabash River in the town of Attica. Eventually the Wabash River converges with the Ohio River in southwestern Indiana.

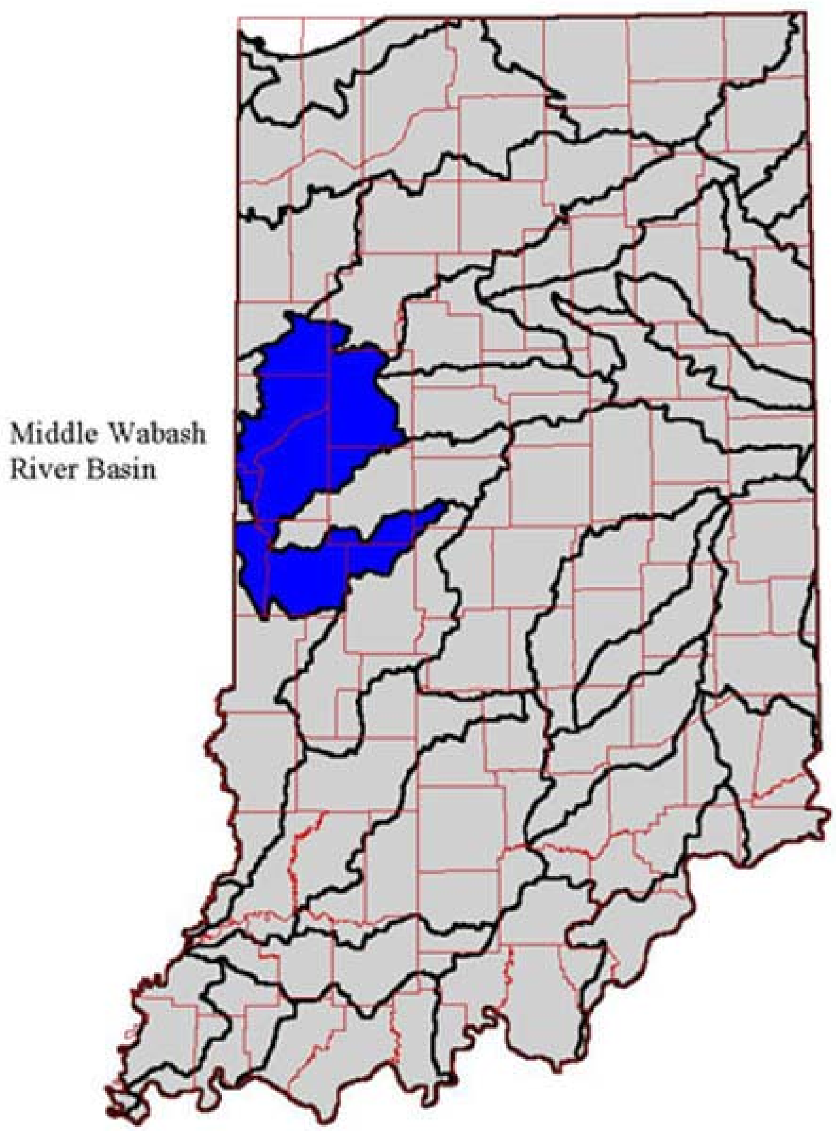

FIGURE 3. Middle Wabash River Basin.

It is important to note that all tributaries to Mud Pine Creek and Goose Creek are legal drains. Legal drains are important for necessary water conductance to sustain a variety of land uses, including agriculture. Disturbance to the system is inevitable due to periodic drainage improvement projects. Additionally, projects constructed within the drainage easement require County Drainage Board permission. Some projects may not be permitted should they impede drainage.

The drainage basin of Mud Pine Creek was formed during the most recent retreat of the Pleistocene or Quaternary Era. The advance and retreat of the Wisconsin glaciers and the deposits left by the glacial lobes shaped much of the landscape found in the northern two-thirds of Indiana (Wayne, 1966). In the study area, the receding glacier left nearly level to rolling topography characterized by "dark prairie soils that are high in organic matter and natural fertility and were formed in moderately heavy limy glacial till deposits" (Ulrich, 1966).

The study watershed is located in the Grand Prairie Section of the southern portion of the Grand Prairie Natural Region (Homoya et al., 1985). The Grand Prairie Natural Region occupies most of the northwest area of the state and is bordered by the Valparaiso Moraine in the north, the Wabash River Valley in the south, and the Maxinkuckee Moraine in the east. Prior to European settlement, vast expanses of tall grass prairie covered the region and many of the species characteristic of eastern deciduous forests are not found in the area (Homoya et al., 1985). As only remnants of the grand prairie are known to exist, this region is considered the most altered of all natural regions in the state. Little is known about the prairie plant community composition; however, small remnants of upland prairie in railroad right-of-ways and in old cemeteries contain little and big bluestem, Indian grass, switchgrass, side-oats grama, compass plant, along with many other species. Wetter areas also fostered communities of prairie plants like cordgrass, Culver's root, water parsnip, golden alexanders, and bluejoint grass. Although relatively rare, other community types in the region included savannah, marsh, pond, bog, and forest areas. Forests were primarily associated with riparian corridors and small oak groves. The first plat of Indiana *circa* 1816 documented tall grass prairie as comprising about 17% of the original vegetation of the state (Petty and Jackson, 1966). Homoya et al., 1985 describe streams of the Grand Prairie Natural Region as being silty and of low gradient.

Changes in land use have altered the watershed's natural landscape. Settlers to the region drained wet areas and cleared forests in order to farm soils rich in both nutrients and humic material (decaying organic matter). However, this layer of rich soil was thin and years of crop removal and erosion depleted nutrient supplies. Around 1850, fertilization with potassium and phosphorus began. Fertilization had no effect on crop yield until 1940 when Dr. George Scarseth discovered that massive doses of nitrogen could significantly increase productivity. Technology and industry have increased and continue to increase farm production. Today, approximately 89% of the watershed is utilized for agricultural purposes.

Installation of subsurface tile drain networks, excavation of drainage channels, and straightening of streams has resulted in conversion of prairies and wetlands to agriculture. The effect of these drainage activities on water quality has been negative, resulting in off-site, downstream water flow and quality concerns. In a review of agricultural practices and their impacts on the natural structure and function of aquatic systems, Menzel (1983) concluded that effects other than water quality problems have emerged. These include alterations in water quantity, habitat structure, and energy transfer within streams.

Only a small number of studies have been conducted to document water quality and health within the Upper Mud Pine Creek Watershed, and the Indiana Department of Environmental Management (IDEM) has never assessed the Lower Wabash River Basin to determine if beneficial uses are being met. However, IDEM 305(b) reports from 1989 to the present have indicated non- or only partial support of beneficial uses at sampling sites in the Upper Wabash River Basin, and a Northwest-Central Indiana Erosion Study conducted in 1989 identified 12,913 acres of major erosion problem areas within the study watershed. Evidently, human impacts within this river basin are having an adverse effect on water quality and beneficial uses.

Because there is little information about this watershed and in order to gain a better understanding of it, the Benton County Soil and Water Conservation District (SWCD) applied for and received funding through the Indiana Department of Natural Resources (IDNR) Lake and River Enhancement (LARE) Program for a watershed diagnostic study. The purpose of this study is to describe the conditions in the watershed, identify potential problems, and make prioritized recommendations addressing these problems. This study includes a review of historical data and information, correspondence with landowners, business owners, and state and local regulatory agencies, collection of stream water quality samples and benthic macroinvertebrates, stream habitat quality evaluation, and field investigations identifying land use patterns and locations for best management practice (BMP) installation. This report documents the results of the study.

REVIEW OF EXISTING INFORMATION

Population and Demographics

The population of Benton County has contracted by 28.2% since 1900 (STATS Indiana, 2001). On average, about 53 people/square mile live in the three townships encompassed by the Upper Mud Pine Creek Watershed (Table 1). The largest (Fowler) and fourth largest (Boswell) towns in Benton County are located either partially or completely within the study area. The population of Fowler was 2,319 in 1980 (United States Department of Commerce, 1981) and 2,315 in 2000 (STATS Indiana, 2001). The population of Boswell has remained stable as well (810 people in 1980 and 823 in 2000).

TABLE 1. Population structure of the three townships encompassed by the Upper Mud Pine Creek Watershed.

Township	Township Population	People/square mile
Center	2,854	80
Oak Grove	1,694	47
Grant	1,142	32

Source: STATS Indiana, 2001.

Physiography and Geology

The surficial physiography and geology of the study watershed area is the result of the most recent glacial period known as the Wisconsin Age that began about 70,000 years ago. Prior to the Wisconsin Age, Indiana had been glaciated twice, though the Wisconsin glacier can be credited with building topography in the north region of Indiana. During the main advance about 21,000 years ago, the Wisconsian glacier covered two-thirds of the state. Numerous glacial advances and retreats resulted in moraine deposition and the formation of Indiana topography as it is known today.

The first two retreats of the Wisconsin Age glaciers that came from the northeast deposited the Shelbyville and Crawfordsville/Chatsworth Moraines (Figure 4) and established the current topography of the Upper Mud Pine Creek about 20,000 years ago. Consequently, the retreat created a "glaciate plain where a variety of unconsolidated deposits of Wisconsinan Age are present including dune sand, lacustrian sediment, outwash plain sediments (sand and gravel), and till (end and ground moraines) (Homoya et al., 1985). These deposits are collectively called the Trafalgar Formation. These Trafalgar tills are mostly composed of bedrock from Canada where the glaciers originated.

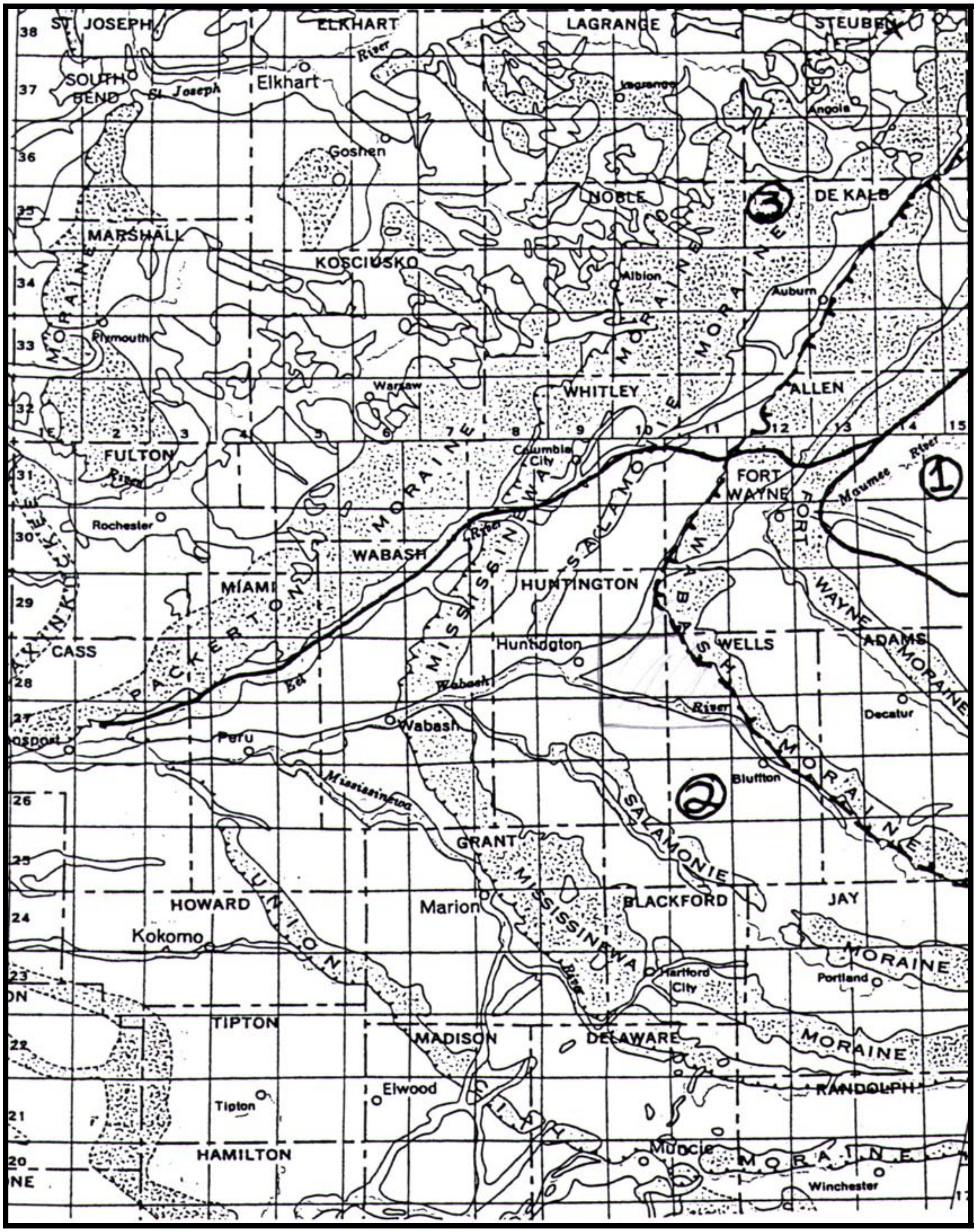

FIGURE 4. Moraine deposits in northern Indiana from the Wisconsin Glacial Period.
Source: Atlas of Mineral Resources of Indiana, Map No. 10.

In physiographic terms, the Upper Mud Pine Creek Watershed is part of the Tipton Till Plain, the largest physiographic unit in Indiana (Schneider, 1966). The Tipton Till Plain is an almost completely flat to gently rolling glacial plain. Although most of the till plain is featureless, several low, poorly developed, end moraines cross it. Streams in the area typically are silty and of low gradient.

The glacial topography of the area is underlain by shale bedrock formed during the Devonian and Mississippian Ages about 20 to 60 million years ago (Gutschick, 1966). Before glaciers deposited drift over the area, the landscape consisted of shale, sandstone, limestone, and dolomite bedrock. This bedrock is now covered by glacial deposits that are as much as 260 feet thick in places (Barnes, 1989).

Watershed Physical Characteristics
The Upper Mud Pine Creek Watershed totals 41,797 acres (16,922 ha or 65.3 square miles) and is part of the Lower Wabash River Basin. Water from Mud Pine Creek discharges into Big Pine Creek southwest of Pine Village in Warren County. Big Mud Pine Creek joins the Wabash River in the town of Attica. Eventually the Wabash River converges with the Ohio River in southwestern Indiana. The Ohio River in turn is part of the larger Mississippi River System.

Tables 2 and 3 contain overview data for the watershed including subwatershed area and stream lengths for all named streams. Subwatershed boundaries were defined based on topography and chemical, physical, and biological sampling sites utilized during this study. It is often desirable to consider subwatersheds or subdrainages because: 1) human communities are organized within small areas (like the town of Boswell is located on Gillen Ditch in the Goose Creek Subwatershed); 2) the subdrainage scale allows for the identification of areas where specific management practices can be recommended and instituted; 3) large watershed units may be too expensive to restore while treatment of small areas may provide measurable water quality improvement (O'Leary et al., 2001). Additionally, watershed division allows for prioritization of resources to land areas of greatest concern where conservation practices may have the greatest benefit.

TABLE 2. Watershed area for the eight study subwatersheds and for the study area as a whole.

Watershed/Subwatershed	Watershed/Subwatershed Number	Watershed Area
Humbert Ditch	1	5,859 acres (2,372 ha)
Howarth Ditch	2	3,456 acres (1,399 ha)
Wattles Ditch	3	1,299 acres (526 ha)
Seamons Ditch	4	3,729 acres (1,510 ha)
Upper Mud Pine Creek	5	3,023 acres (1,224 ha)
Volz Ditch	6	7,114 acres (2,880 ha)
Goose Creek	7	8,975 acres (3,634 ha)
Lower Mud Pine Creek	8	8,341 acres (3,377 ha)
Study Watershed Total		**41,797 acres (16,922 ha)**

TABLE 3. Stream length of all named streams and length of the entire study drainage system.

Creek/Ditch	Stream Length (miles)	Stream Length (km)
Farrell Ditch	1.76	2.83
Goose Creek	6.39	10.29
Gillen Ditch	6.21	10.00
Mud Pine Creek	15.6	25.03
Volz Ditch	3.23	5.21
Seamons Ditch	8.37	13.48
Budreau Tile	4.72	7.59
Lawson Tile	3.25	5.23
Wattles Ditch	4.08	6.58
Kelly Tile	1.74	2.80
Humbert Ditch	2.66	4.28
Howarth Ditch	4.36	7.01
Unnamed Tributaries	9.05	14.56
Study Drainage System Total	**71.37**	**114.89**

Climate

Indiana Climate

Indiana's climate can be described as temperate with cold winters and warm summers. "Imposed on the well known daily and seasonal temperature fluctuations are changes occurring every few days as surges of polar air move southward or tropical air moves northward. These changes are more frequent and pronounced in the winter than in the summer. A winter may be unusually cold or a summer cool if the influence of polar air is persistent. Similarly, a summer may be unusually warm or a winter mild if air of tropical origin predominates. The action between these two air masses of contrasting temperature, humidity, and density fosters the development of low-pressure centers that move generally eastward and frequently pass over or close to the state, resulting in abundant rainfall. These systems are least active in midsummer and during this season frequently pass north of Indiana" (National Climatic Data Center, 1976). Prevailing winds are generally from the southwest, but are more persistent and blow from a northerly direction during the winter months. Flooding is common in Indiana and occurs in some part of the state almost every year. The months of greatest flooding frequency are December through April. Causes of flooding vary from prolonged periods of heavy rain to precipitation falling on snow and frozen ground.

Study Watershed Climate

The climate of the study watershed is characterized as having four well-defined seasons of the year. Winters average 28ºF (-2.2ºC), while summers are warm, averaging 73ºF (22.8ºC). The growing season typically begins in early May and ends in early October. Yearly annual rainfall averages 37 inches (94 cm), while winter snowfall averages about 25 inches (63.5 cm). The ten-year frequency, one-hour duration, rainfall intensity for the area is 1.98 inches/hour (5 cm/hr). During summers, relative humidity varies from about 60 percent in midafternoon to near 80 percent at dawn. Prevailing winds typically blow from the southwest, but westerly and northwesterly winds predominate in the winter.

In 2000, over 37 inches (94 cm) of precipitation (Table 4) was recorded at Boswell in the southern portion of the Upper Mud Pine Creek Watershed (http://shadow.agry.purdue.edu/sc.index.html). This amount exceeded that received during 1999, which was widely recognized as a drought year. When compared to the 30-year average rainfall for the area, 2000 was also a dry year. Year 2001 was characterized by significant wetter-than-normal and drier-than-normal periods. Summer months and the month of October were uncharacteristically wet. By October of 2001, the area had received about 9 inches more rain than would have been received by a normal October.

TABLE 4. Monthly rainfall data (in inches) for year 2000 and 2001 as compared to average monthly rainfall. All data was recorded at the Boswell gage station which is in the Upper Mud Pine Creek Watershed. Averages are based on available weather observations taken during the years of 1961-1990 in Kentland, Indiana just north of the study area (http://shadow.agry.purdue.edu/sc.index.html).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
2000	1.07	2.17	1.32	1.79	4.31	4.99	8.06	2.30	2.81	2.47	2.77	1.95	36.01
2001	0.77	3.70	0.80	4.24	4.11	4.66	5.15	6.15	2.71	8.76	2.03	4.07	47.15
Average	1.53	1.55	2.91	3.55	3.90	4.17	4.24	3.71	3.44	2.72	3.00	2.71	37.43

Soils

Introduction

The soil types found in the Upper Mud Pine Creek Watershed in Benton and Warren Counties are a product of the original parent materials deposited by the glaciers that covered the area 15,000 to 20,000 years ago. The main parent materials found in the counties are glacial outwash and till, lacustrine material, alluvium, and organic materials that were left as the glaciers receded. The interaction of these parent materials with the physical, chemical, and biological variables found in the area (climate, plant and animal life), time, and the physical and mineralogical composition of the parent material formed the soils located in the counties today.

Surficial glacial deposits in Benton County are characteristically fine loams, silt loams, clay loams, and silty clays within the Chatsworth and Crawfordsville Moraines, the somewhat diffuse morainal structures drained by the watershed (Figure 4). The USDA soils survey of Benton County (Barnes, 1989) classifies soil associations within the study area into 3 different types at a general level. Table 5 contains information on these general soil associations and where within the general topography they may be found.

TABLE 5. Characteristics of general soil associations found within the study watershed.

Association	Description	Texture	Formation Process	Location
Drummer-Comfrey-Tippecanoe	Silt loam, silty clay loam, and clay loam	Fine	In silty deposits, outwash, and alluvium	On floodplains, outwash terraces, and outwash plains
Corwin-Odell-Chalmers	Silt loam, silty clay loam, and clay loam	Fine	In glacial till and in silty deposits	On end moraines
Gilboa-Chalmers-Selma	Silt loam, silty clay loam, and clay loam	Fine	In silty deposits, outwash, and glacial till	On end moraines and ground moraines

Source: Barnes, 1989.

Highly Erodible Soils

Soils in the watershed and their ability to erode or sustain certain land use practices, can impact the water quality of the river systems with which they converge. For example, highly erodible soils are, as their name implies, easily erodible. Soils that erode from the landscape are transported to waterways where they impair water quality, interfere with recreational uses, and impair aquatic habitat and health. In addition, such soils carry attached nutrients, which further impair water quality by increasing production of plant and algae growth. Soil-associated chemicals like some herbicides and pesticides can kill aquatic life and damage water quality.

Soil unit names considered highly erodible by the Natural Resources Conservation Service (NRCS) are included in Table 6. It is important to note that highly erodible soil designations are based on county-wide soil surveys, and the soils at various locations have not necessarily been field checked. The Benton County FSA lists 13 potentially highly erodible soil types. Due to its location on the flatter till and outwash plain area, these soil types are not common in the study watershed. The diffuse nature of the Chatsworth and Crawfordsville Moraines resulted in fairly uniform, flat topography that is not as prone to erosion as more steeply sloped areas. The exact areas where soil erosion could be of concern will be discussed in the Highly Erodible Land (HEL) section.

TABLE 6. Soil units within the watershed area considered highly erodible by the NRCS office of Benton County.

Soil Unit	Soil Name	Soil Description
BaB2	Barce loam	2-6% slopes, eroded
BdB2	Barce silt loam	2-6% slopes, eroded
FoB2, FpB2	Foresman silt loam	1-5% slopes, eroded
FrB2	Foresman loam	1-5% slopes, eroded
MbB2	Markham silt loam	2-6% slopes, eroded
MlB2	Miami silt loam	2-6% slopes, eroded
MuB3	Montmorenci loam	2-6% slopes, severely eroded
MxB2	Montmorenci silt loam	2-6% slopes, eroded
RuB2	Rush silt loam	2-6% slopes, eroded
SxB2	Swygert silty clay loam	2-6% slopes, eroded
VaB2	Varna silt loam	1-5% slopes, eroded
WhB2	Wea silt loam	2-6% slopes, eroded

Source: PHEL List, Benton County Farm Service Agency.

These soil types are limited for certain classes of land use, and erosion hazard is a potential management concern. Erosion and runoff are hazards for the soils listed in Table 6. The Swygert silty clay loam (SxB2) is somewhat more erosion-prone because it is a wet soil resulting in poor root development in non-hydrophytic plant species like corn and soybeans. Barnes (1989) suggests that erosion can be properly controlled by utilizing conservation structures and practices: 1) water and sediment control basins; 2) diversions; 3) terraces; 4) conservation tillage; 5) cover crops; 6) grade stabilization structures; and 7) grassed waterways. Conservation management strategies will be discussed in further detail in the Best Management Practice Section.

Highly Erodible Land

Highly Erodible Land (HEL) is a designation used by the Farm Service Agency (FSA). For a field or tract of land to be labeled HEL by the FSA, at least one-third of the parcel must be situated in highly erodible soils. Unlike the soil survey, these fields must be field checked to ensure the accuracy of the mapped soils types. Farm fields mapped as HEL are required to file a conservation plan with the FSA in order to maintain eligibility for any financial assistance from the USDA. Figure 5 shows the location of HEL fields in the study watershed. Only approximately 469 acres (190 ha) of HEL exist within boundaries of the study watershed. This is about 1% of the Upper Mud Pine Creek Watershed. It is important to note here that the FSA will only track HEL if the tract of land is used to produce crops. Parcels of land may be highly erodible but not recorded as such if the parcel is not used for production. Therefore the 1% may be an underestimate of the actual amount of HEL in the watershed.

Table 7 breaks the information down by subwatershed. The Lower Mud Pine Creek has the most HEL acreage, and 2.8% of its watershed is mapped as HEL. A small portion of the Goose Creek Subwatershed (2.3%) is also considered HEL. The Seamons Ditch and Volz Ditch contain tiny tracts of HEL as well.

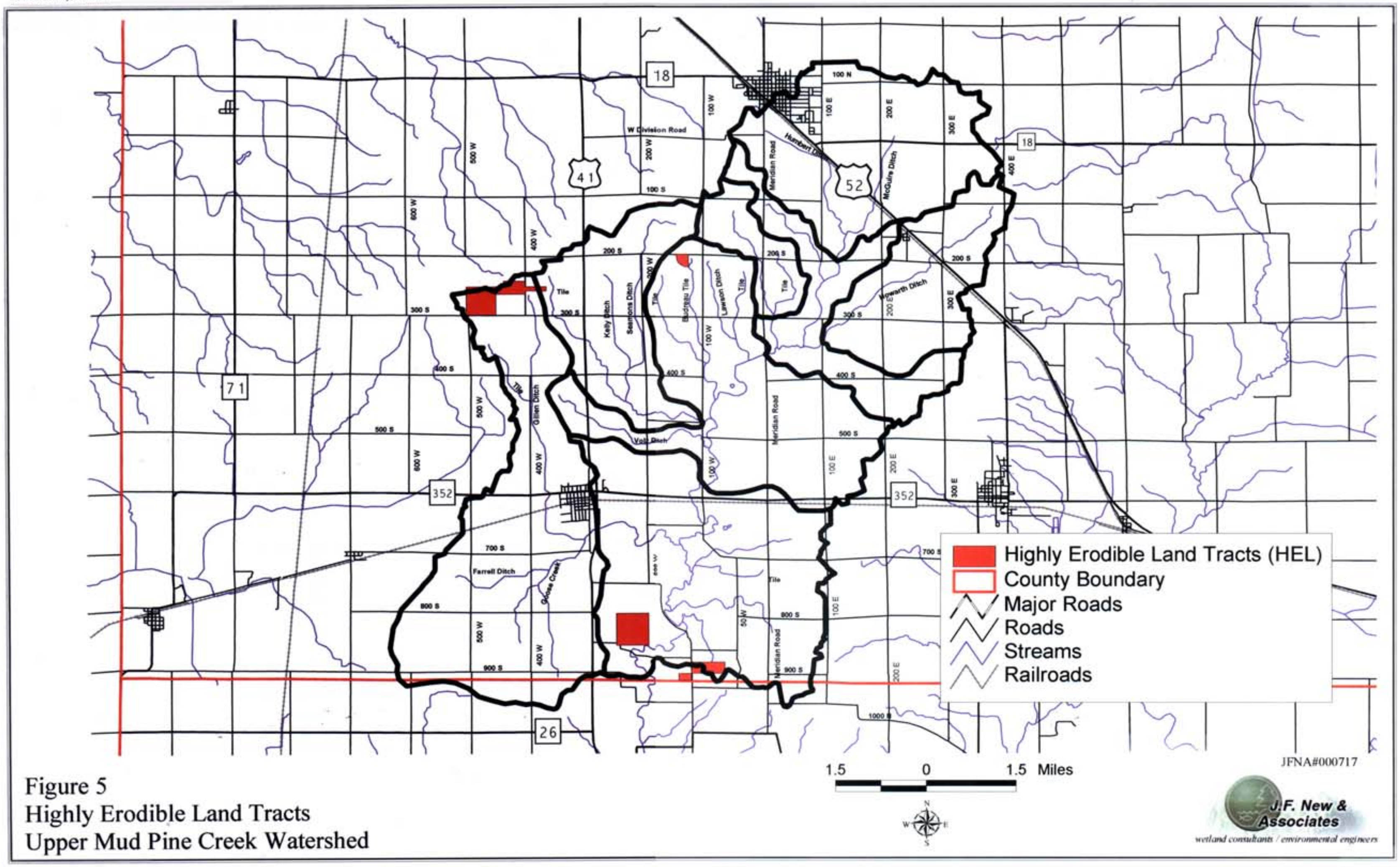

Figure 5
Highly Erodible Land Tracts
Upper Mud Pine Creek Watershed

TABLE 7. Area mapped in highly erodible map units by subwatershed and percent of each subwatershed that is considered highly erodible.

Subwatershed	Acres	Hectares	Percent of Subwatershed
Humbert Ditch	0.0	0.0	0.0%
Howarth Ditch	0.0	0.0	0.0%
Wattles Ditch	0.0	0.0	0.0%
Seamons Ditch	6.5	2.6	0.2%
Upper Mud Pine Creek	0.0	0.0	0.0%
Volz Ditch	23.8	9.6	0.3%
Goose Creek	203.2	82.3	2.3%
Lower Mud Pine Creek	235.6	95.4	2.8%
Total	**469.1**	**189.9**	**1.1%**

Source: GIS coverages based on information from the Benton County SWCD.

Relative to other areas of greater relief in the state, the Upper Mud Pine Creek Watershed contains little highly erodible land. (For example, about 9,015 acres (33%) of the Brooks Creek Watershed in Jay County are classified as highly erodible.) Figure 6 demonstrates that in general most of the HEL is concentrated in the south and west areas of the watershed. These areas lie on more steeply sloped hillsides where soils are more likely to erode. The Humbert Ditch, Howarth Ditch, Wattles Ditch, and Upper Mud Pine Creek Subwatersheds lie in the relatively flat outwash plain areas and contain no HEL area.

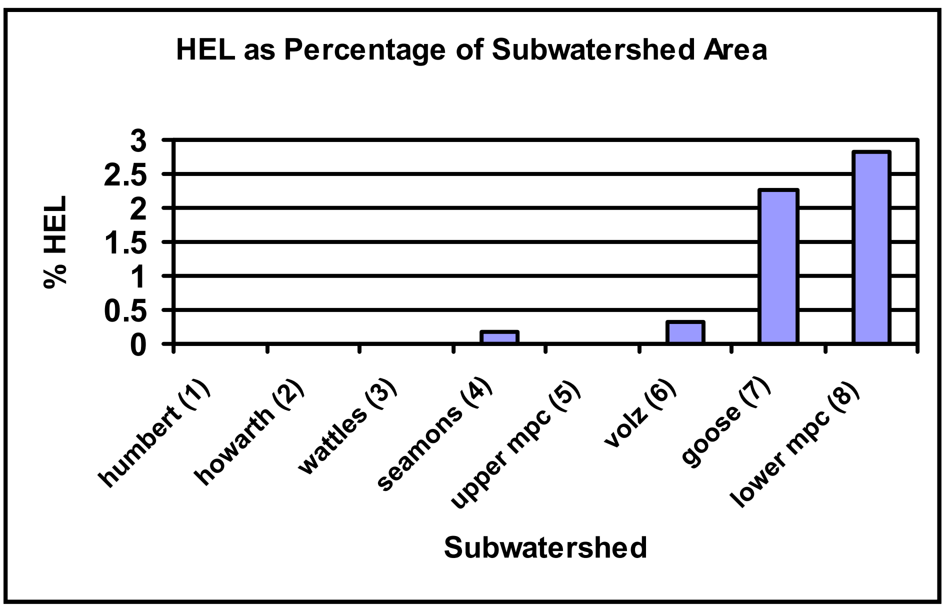

FIGURE 6. Highly erodible land as a percentage of subwatershed area. "mpc" stands for Mud Pine Creek.

When comparing Figures 5 and 7 it is clear that in many areas HEL and developed agricultural land uses overlap. According to the figures, most of the highly erodible tracts in the watershed are currently being used for production. This type of land use on highly erodible, marginal soils has definite implications for the receiving waterway's ability to support its beneficial uses. Consideration and implementation of Best Management Practices (BMPs) on these tracts is merited. BMPs will be discussed in more detail later in the report.

Considerations for On-Site Wastewater Disposal Systems
Background Information
Nearly half of Indiana's population lives in residences having private waste disposal systems. As is common in rural Indiana, septic tanks and septic tank absorption fields are utilized for wastewater treatment in the Upper Mud Pine Creek Watershed. This type of wastewater treatment system relies on the septic tank for primary treatment to remove solids and the soil for secondary treatment to reduce the remaining pollutants in the effluent to levels that protect surface and groundwater from contamination.

A variety of factors can affect a soil's ability to function as a septic absorption field. Seven soil characteristics are currently used to determine soil suitability for on-site sewage disposal systems: position in the landscape, slope, soil texture, soil structure, soil consistency, depth to limiting layers, and depth to seasonal high water table (Thomas, 1996). The ability of soil to treat effluent (waste discharge) depends on four factors: the amount of accessible soil particle surface area, the chemical properties of the surfaces, soil conditions like temperature, moisture, and oxygen content, and the types of pollutants present in the effluent (Cogger, 1989).

The amount of accessible soil particle surface area depends both on particle size and porosity. Because they are smaller, clay particles have a greater surface area per unit volume than silt or sand and therefore, a greater potential for chemical activity. However, soil surfaces only play a role if wastewater can contact them. Soils of high clay content or soils that have been compacted often have few pores that can be penetrated by water and are not suitable for septic systems because they are too impermeable. Additionally, some clays swell and expand on contact with water closing the larger pores in the profile even more. On the other hand, very coarse soils may not offer satisfactory effluent treatment either because the water can travel so rapidly through the soil profile. Soils located on sloped land also may have difficulty in treating wastewater due to reduced contact time.

Chemical properties of the soil surfaces are also important for wastewater treatment. For example, clay materials all have imperfections in their crystal structure which gives them a negative charge along their surfaces. Due to their negative charge, they can bond cations of positive charge to their surfaces. However, many pollutants in wastewater are also negatively charged and are not attracted to the clays. Clays can help remove and inactivate bacteria, viruses, and some organic compounds.

Environmental soil conditions influence the microorganism community which ultimately carries out the treatment of wastewater. Factors like temperature, moisture, and oxygen availability influence microbial action. Excess water or ponding saturates soil pores and slows oxygen transfer. The soil may become anaerobic if oxygen is depleted. Decomposition process (and therefore, effluent treatment) becomes less efficient, slower, and less complete if oxygen is not available.

Many of the nutrients and pollutants of concern are removed safely if a septic system is sited correctly. Most soils have a large capacity to hold phosphate. On the other hand, nitrate (the end product of nitrogen metabolism in a properly functioning septic system) is very soluble in soil solution and is often leached to the groundwater. Care must be taken in siting the system to avoid well contamination. Nearly all organic matter in wastewater is biodegradable as long as oxygen is present. Pathogens can be both retained and inactivated within the soil as long as conditions are right. Bacteria and viruses are much smaller than other pathogenic organisms associated with wastewater and therefore, have a much greater potential for movement through the soil. Clay minerals and other soil components may adsorb them, but retention is not necessarily permanent. During stormflows, they may become resuspended in the soil solution and transported in the soil profile. Inactivation and destruction of pathogens occurs more rapidly in soils containing oxygen because sewage organisms compete poorly with the natural soil microorganisms, which are obligate aerobes requiring oxygen for life. Sewage organisms live longer under anaerobic conditions without oxygen and at lower soil temperatures because natural soil microbial activity is reduced.

The Study Watershed Area

Soil conditions such as slow permeability and high water table, coupled with poor design, faulty construction, and lack of maintenance reduce the average life span of septic systems in Indiana to 7-10 years (Jones and Yahner, 1994). Likewise, several onsite systems located in morainal soils in other neighboring areas are known to perform poorly or to have failed completely (Indiana University/Purdue University, 1996). Localized soil-geologic conditions are responsible for most of the problems. In fact in Wells County, the Indiana State Department of Health and the Wells County Health Board have instituted a moratorium on residential development within the Wabash End Moraine in an area known as “Buttermilk Ridge”, a part of Union Township (Section 14, T28N, R11E). Although no extensive studies have been conducted within the Chatsworth or Crawfordsville Moraines of the immediate watershed area, soil types there share similar soil composition characteristics with soils like those found in the Wabash End Moraine.

The NRCS ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields on soils in the moderately or severely limited categories generally requires special designs, planning, or maintenance to overcome the limitations. Table 8 summarizes the predominant soil series located in the study watershed area in terms of their suitability for use as a septic tank absorption field.

TABLE 8. Dominant soil types in the Upper Mud Pine Creek Watershed and their suitability for on-site wastewater treatment systems.

Name	Symbol	Depth to Water Table	Suitability for Septic Absorption Field
Drummer silty clay loam	Du, Dv, Dx	0.5-2 ft	Severe: ponding
Comfrey silty clay loam	Ck, Cm	0.5-1 ft	Severe: flooding, ponding
Tippecanoe silt loam	TlA, TlB	3-6 ft	Severe: wetness
Corwin silt loam	CsA, CsB, CsC2	2-4 ft	Severe: wetness, percs slowly
Odell silt loam	OlA, OlB	1-3 ft	Severe: wetness, percs slowly
Chalmers silty clay loam	Ch	0.5-1 ft	Severe: wetness, percs slowly
Gilboa silt loam	GlA, GlB	1-3 ft	Severe: wetness, percs slowly
Selma silty clay loam	Sh, Sk	0.5-1 ft	Severe: ponding, percs slowly

Source: Soil Survey of Benton County.

All of the 8 major soil types present in the study drainage are not suited for septic leachate treatment. In fact most soil types in the watershed are severely limited for use as septic system substrate and are generally not conducive to the satisfactory operation of conventional on-site treatment systems. The Tippecanoe (TlA, TlB), Corwin (CsA, CsB, CsC2), Odell (OlA, OlB), and Gilboa (GlA, GlB) silt loams tend to be wet, poorly drained soils of slow permeability. The Drummer (Du, Dv, Dx), Chalmers (Ch), and Selma (Sh, Sk) silty clay loams are nearly level, poorly drained soils that are often ponded by water from adjacent slopes. The Comfrey (Ck, Cm) silty clay loams are occasionally flooded and are subject to ponding. All of the soils are threatened by high water tables which contribute to soil saturation and wetness. Characteristic wetness can lead to anoxic conditions and improper treatment within leach fields. If conventional systems must be installed, it is recommended that systems be: installed with perimeter subsurface drains to lower the water table, installed with an enlarged leach field to offset slow permeability, and constructed when the soil is dry to avoid soil sealing and compaction.

E. coli levels measured during the current study were low and do not indicate severe waste contamination in Mud Pine Creek or its tributaries. Although *E. coli* counts in 11 of the 17 samples collected exceeded the 235 col/100 ml Indiana state standard for full-contact recreation, the highest count measured was only 350 col/100 ml; on average samples only contained 17 col/100 ml more than the standard of 235. Despite these results, many of the dominant soil types in the study watersheds have severe limitations for proper septic function (Table 8). Geologic conditions in many parts of the diffuse moraine deposits are not likely to promote satisfactory septic system function resulting in surface and groundwater pollution. To address these issues and concerns, development should proceed with caution especially in soils unsuited for conventional treatment systems. Competent soil scientists that are familiar with conditions should evaluate potential development sites for evidence of poor water movement, soil development, or filtering ability. Alternative technology, like the mound system, the at-grade system, the pressure-dosed system, or wastewater wetlands may provide a solution in soils that are unsuitable. Some soils may be suitable for alternating field technology which requires that a second field be available to accept effluent while the primary field "rests". Enlarged septic fields should be installed to increase the area of absorption. It is important to note, however, that some soils are too wet, too shallow, too impermeable, too steep, or too well-drained for any type of system.

Once the proper technology has been installed, proper maintenance is very important. Depending on the size of the system and the loading to it, systems should be cleaned out every 2-5 years. Property owners should divert surface runoff away from absorption fields, keep a cover of vegetation over the field, and keep foot and vehicular traffic over the field to a minimum. Pressure on septic systems can also be reduced by common water conservation practices like shorter showers and less flushing and rinsing.

Soil Discussion and Summary

The type of soils in a watershed and the land uses practiced on those soils can impact the quality of the water leaving the watershed. Highly erodible land is concentrated primarily in the south and west areas of the watershed; however, relative to other regions of Indiana, the Upper Mud Pine Creek contains little highly erodible land tracts. The Lower Mud Pine Creek and Goose Creek Subwatersheds contain the most HEL per unit of watershed acreage at 2.3 and 2.8% respectively. Soil erosion contributes sediment to the rivers reducing water quality downstream and interfering with aquatic habitat and recreational uses. Nutrients attached to eroded soils fertilize and increase aquatic production. Additionally, soil eroding from the landscape silts in ditches and drainageways necessitating costly dredging maintenance projects. Not only does the sediment hinder water conveyance, it also provides a nutrient-rich substrate for rooted aquatic plant growth. Nutrients and nutrient-rich sediment can promote the growth of nuisance levels of algae and plants downstream in other waterbodies. Consequently, conservation methods and best management practices (BMPs) should be utilized when soils are disturbed in these areas. This includes residential development and farming practices in highly erodible soils.

Soil type should also be considered in siting septic systems. Some soils do not provide adequate treatment for septic tank effluent. Although much of the land in the study watersheds is mapped in soils that rate as severely limited or generally unsuitable for use as septic tank absorption fields, *E.* coli data collected during this study does not indicate that systems are failing in large numbers. This is typical for much of Indiana, as research by Dr. Donald Jones suggests that 80% of the soils in Indiana are unsuitable for wastewater treatment (Grant, 1999).

Pollution from septic tank effluent can affect waterways, the life it supports, and its users in a variety of ways. It can contribute to eutrophication (overproduction) and water quality impairment of lakes and other waterbodies in the watersheds. In addition, septic tank effluent potentially poses a health concern for users of both surface and groundwater in the watersheds. Swimmers, anglers, or boaters that have body contact with contaminated water may be exposed to waterborne pathogens. This is an issue of concern for Mud Pine Creek, its tributaries, and its receiving waterbody Big Pine Creek, since according to Indiana State statutes, these waterbodies should support contact recreation as a beneficial use (IDEM, 2000; IAC, 2000). Fecal contaminants can be harmful to humans and cause serious diseases, such as infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illness. Additionally, nitrogen and pathogens may also leach into the groundwater compromising well water for drinking.

Land Use

Figure 7 and Table 9 present land use information for the Upper Mud Pine Creek Watershed. Land use data was obtained from the United States Geological Survey (USGS) Multi-resolution Land Coverage (MRLC) project. This data was checked with recent aerial photography and in some areas was field checked during the windshield tour. Data was last corrected to reflect current conditions in the watershed during October 2001. Land use data for each subwatershed is presented in Appendix 1.

TABLE 9. Land use in the Upper Mud Pine Creek Watershed.

Land Use	Area (acres)	Area (ha)	Percent of Watershed
Bare rock/sand/clay	0.4	0.2	0.0%
Deciduous forest	347.2	140.6	0.8%
Emergent herbaceous wetland	14.8	6.0	0.0%
Evergreen forest	30.9	12.5	0.1%
Grassland/herbaceous	199.5	80.8	0.5%
High intensity residential	93	37.7	0.2%
High intensity commercial/ind/trans	211.6	85.7	0.5%
Low intensity residential	220.9	89.4	0.5%
Open water	9.8	4.0	0.0%
Other grasses (urban, parks, rec.)	54.6	22.1	0.1%
Pasture/hay	4,027.4	1,630.5	9.6%
Row crops	36,486.3	14,771.3	87.3%
Small grains	0.7	0.3	0.0%
Woody wetlands	100.1	40.5	0.2%
Total	**41,797**	**16,922**	**100%**

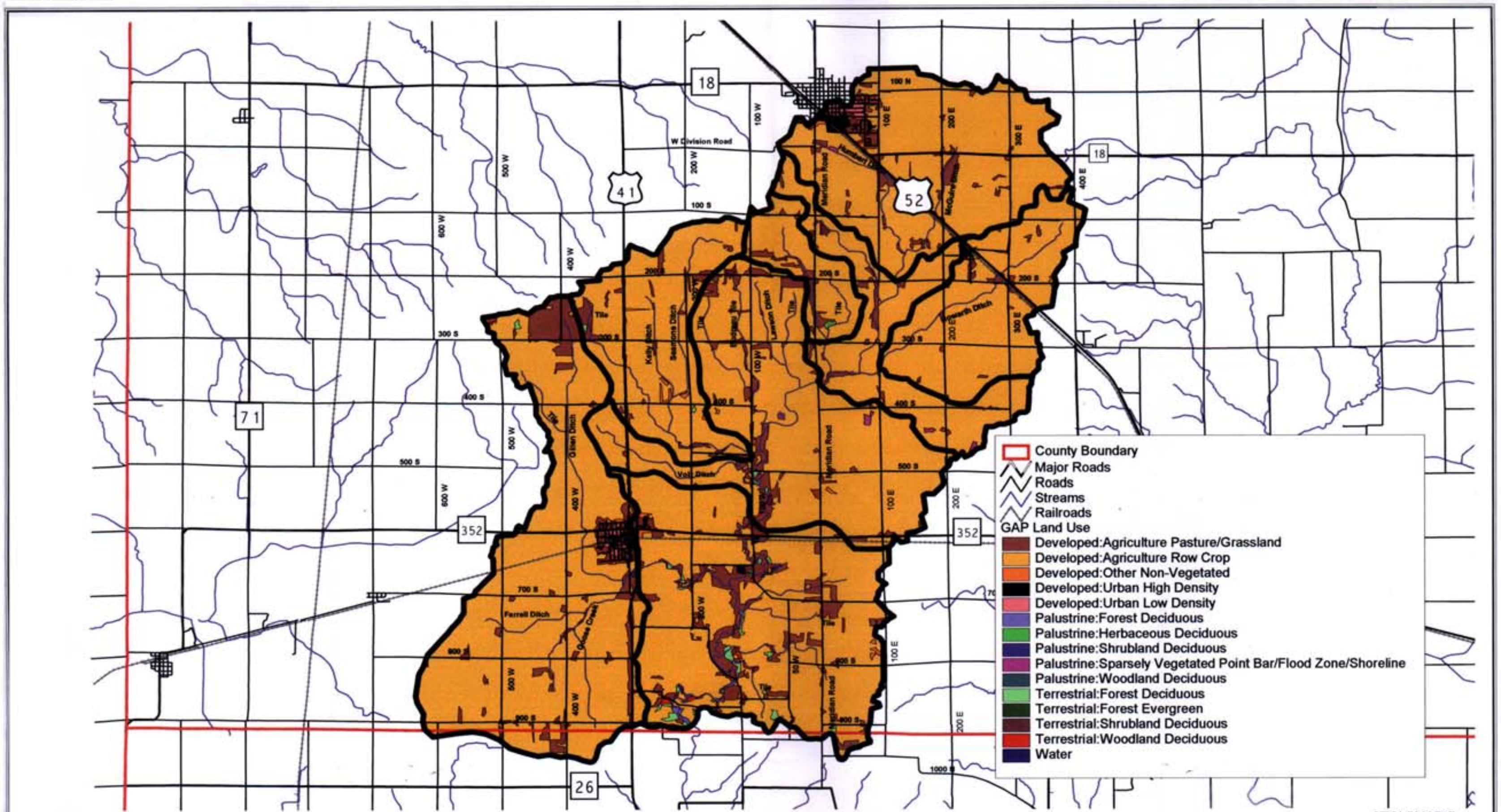

Figure 7
Land Use and Land Cover
Upper Mud Pine Creek Watershed

Approximately 97% of the watershed is used for agricultural purposes, including cropland, pasture, and agricultural woodlots. This percentage is close to that estimated by the U.S. Census of Agriculture (2000) for Benton County (98.8%). Over eighty-seven percent is used for row crop production. Table 10 contains more detailed U.S. Census of Agriculture (2000) data for Benton and Warren Counties.

TABLE 10. Detailed 2000 U.S. Census of Agriculture data for Benton and Warren Counties.

County	# of Farms	Land in Farms (acres)	Total Land (acres)	Percent of County Farmed
Benton	433	256,820	260,052	98.8%
Warren	378	184,653	233,541	79%

Source: U.S. Census of Agriculture, United States Department of Commerce (2000).

In general, row crop agriculture dominates land use throughout the subwatersheds (Figure 8). The Goose Creek Subwatershed is the most diverse with respect to different types of land use while the Volz Ditch and Upper Mud Pine Creek Subwatersheds are the least diverse. Municipalities of Fowler (in the Humbert Subwatershed), Swanington (in the Howarth Subwatershed), and Boswell (in the Goose Creek Subwatershed) contribute small amounts of high intensity residential, commercial, and industrial land use to the watershed.

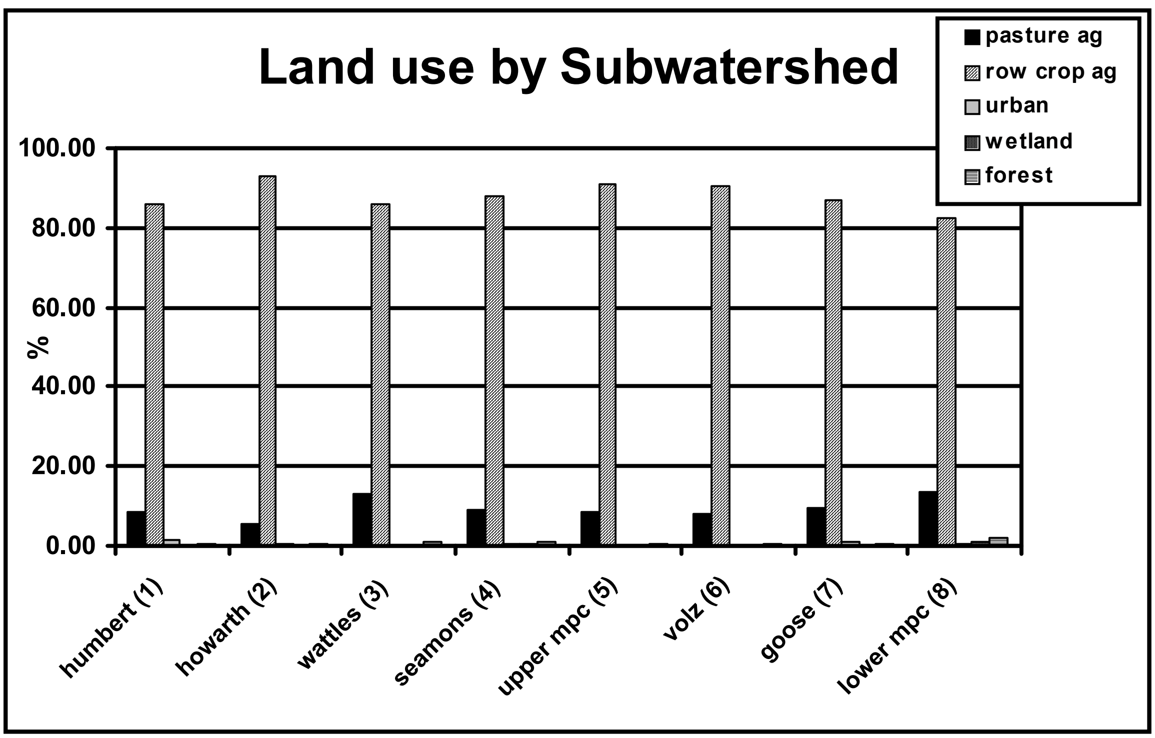

FIGURE 8. Percent of total subwatershed area in use for the broad land use categories: pasture agriculture, row crop agriculture, urban, wetland, and forest.

Soybeans, corn, and forage are the major crops grown in Benton County. Although exact percentages of each crop were not recorded for the study watershed, 49.1% of the agricultural fields in the county were planted with soybeans and 49.5% in corn in 2000 (Purdue University Cooperative Extension Service, 2001). It is likely that the study watersheds closely mirror these percentages. Table 11 contains more detailed information regarding percentage and acreage of Benton County fields used to produce different crops and commodities and estimated numbers of cattle in 2001. Note that Benton County ranks second in the state for soybeans and third in the state for corn.

TABLE 11. Percent and acreage of Benton County fields with indicated present crop for year 2001. Percentages are taken from a field sampling of points along transects across the counties. No data are available for percent or acreage of land in permanent pasture. The number of beef cattle, dairy cattle, and total cattle in the counties in 2000 are also given. The last column provides production rank for each county in the state for each of the commodities.

Crop/Commodity	Percent or Number	Acreage of Land	Rank in State
Benton County			
Soybeans	49.1%	120,400	2
Corn	49.5%	119,000	3
Small Grains	0%	0	NR
Hay/Forage	0.88%	2,300	79
Beef Cattle	900		75
Dairy Cattle	0		NR
Total Cattle	2,800		84

Source: Purdue Cooperative Extension Service, 2000 and U.S. Census of Agriculture, 2000.
NR=Not ranked.

Prime farmland is one of several land types classified and recognized by the USDA. Prime farmland is land that is best suited for crops. The land is used for cultivation, pasture, woodland or other production, but it is not urban land or water areas. This type of land produces the highest yields with minimal inputs of energy and economic resources. Farming it results in the least damage to the environment. Therefore, when possible, the optimal land use strategy places industrial and residential development on the marginal lands while keeping prime farmland available for production. According to the USDA soil survey of Benton County, about 253,550 acres or >97% of the acreage in the general area meets prime farmland requirements (Barnes, 1989), and the majority of the land in the Upper Mud Pine Creek Watershed is classified as prime farmland.

“A recent trend in land use in some parts of the county has been the loss of some prime farmland to industrial and urban uses. The loss of prime farmland to other uses puts pressure on marginal lands, which generally are more erodible, wet or droughty, and less productive and cannot be as easily cultivated” (Barnes, 1989). Cultivation of more marginal land also results in more damage to the environment. Although the Upper Mud Pine Creek Watershed is not undergoing rapid urbanization, some new development was noted during the windshield tour (which will be discussed in more detail later), and Barnes (1989) notes that every year small tracts are developed for non-agricultural uses. This type of change in land use will have obvious impacts on water quality, especially if it results in more farming of marginal land elsewhere. Again, careful land use and development planning can minimize the need to produce crops on compromised land.

Aside from row crop agriculture, pastureland constitutes the only other significant land use in the Upper Mud Pine Creek Watershed (about 10% of the total land area). Tracts of pastureland directly border streams in every subdrainage in the Upper Mud Pine Creek Watershed (Figure 7). Most notably, pastureland tracts border significant stream reaches along Gillen Ditch, the southernmost half of Mud Pine Creek, Wattles Ditch, and Humbert Ditch. When pastured livestock is allowed direct access to streams, pastureland use is closely coupled with riparian area degradation and increased soil, nutrient, and bacterial runoff. Efforts should be made to exclude livestock from waterways in these critical areas.

Forested land (about 0.84%), urban land (0.59%), and wetlands (0.23%) represent the only other notable land uses within the study watershed (Figure 7). Few natural areas remain, but in some cases like along the mainstem of Mud Pine Creek in the southern area of the watershed, forests and wetlands directly border stream segments. Not only do these forest areas and wetlands help moderate stream water temperature and velocity, they also offer water storage capacity and sediment and nutrient filtration. Figure 9 further classifies the wetlands based on National Wetland Inventory (NWI) data. According to the NWI data, most wet areas are palustrine, emergent wetlands (Table 12). Due to the small remaining concentration of forest and wetland land use (less than 1% of the watershed) their protection is merited. Farmers should also be encouraged to route drainage tiles toward wetland areas. Riparian buffer area filtration is drastically reduced when drainage tiles completely bypass them, carrying drainage waters directly to the ditch.

TABLE 12. National Wetland Inventory (NWI) data for the Upper Mud Pine Creek Watershed.

Wetland Type	Area (acres)	Area (hectares)
Palustrine Emergent	123.2	49.9
Palustrine Forested	27.2	11.0
Palustrine Scrub/shrub	6.0	2.4
Ponds	19.1	7.7
Riverine	45.7	18.5
Total	**221.2**	**89.5**

Agricultural Best Management Practices (BMPs)

Approximately 87% of the Upper Mud Pine Creek Watershed is utilized for agricultural row crop production. This land use, particularly on highly erodible soils and in other environmentally sensitive areas, can have an impact on water quality downstream. Runoff from farm fields can contain a variety of pollutants including nutrients (nitrogen and phosphorus), herbicides, pesticides, sediment, and bacteria (*E. coli*). In addition, the original creation of agricultural land involved draining low wet areas using drainage tiling. This has decreased the storage capacity of the land and increased peak flows of water in streams and channels in the watersheds. An increase in both the volume and velocity of peak flows typically leads to increases in land erosion and ultimately increases in sediment and sediment-associated particle loading to the receiving waterbody. According to the National Research Council (1993), non-

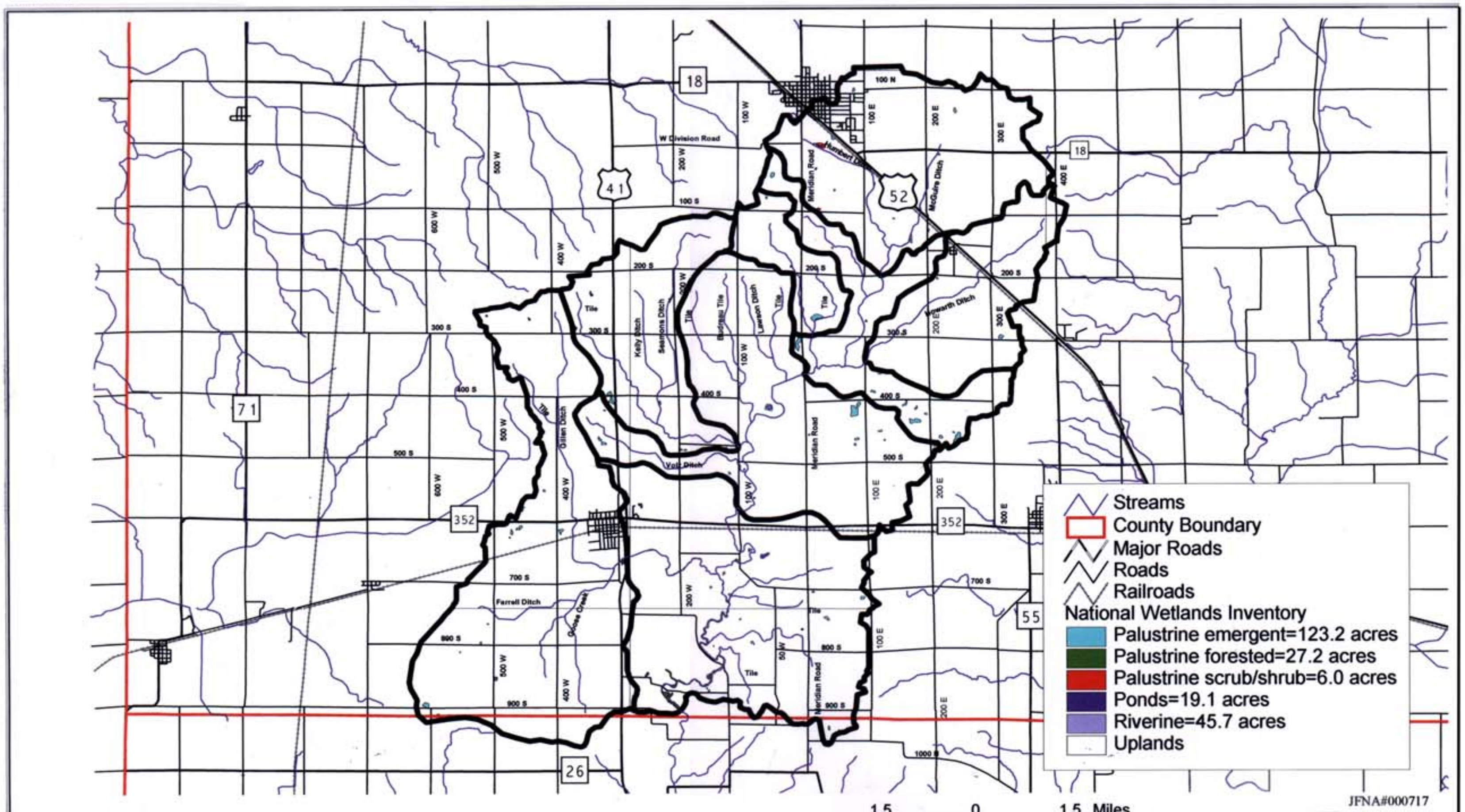

Figure 9
National Wetland Inventory (NWI) Map
Upper Mud Pine Creek Watershed

point source pollution by contaminants in agricultural runoff is a major cause of poor surface water quality in the USA.

Several programs and Best Management Practices (BMPs) have been developed to address non-point source pollution associated with agriculture. BMPs may be structural or managerial in nature (Osmond et al., 1995). Filter strips, riparian buffer strips, grassed waterways, and use of erosion control structures are examples of structural practices, while rotational grazing, conservation tillage, and nutrient and pesticide management, are managerial BMPs. Each is aimed at conservation to help ensure a healthy and productive land through watershed and natural system protection. Programs and BMPs that are currently in use in the study watersheds or that could potentially be used more frequently or consistently are discussed below.

The Conservation Reserve Program

Introduction

The Conservation Reserve Program (CRP) is the single, largest environmental improvement program offered by the federal government. The program arose out of concerns raised by USDA studies conducted in the early 1980s showing that the nation's cropland was eroding and losing soil at a rate of 3 billion tons per year (USDA, 1997). The CRP provides volunteer participants with an annual per-acre rent and 50% of the cost of establishing permanent land cover. In return, participants are required to retire the cropland from production for 10-15 years.

Removing land from production and planting it with vegetation has a positive impact on water quality within the given watershed. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that lakes within ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores. A lower TSI is indicative of lower productivity and better water quality.

The New Conservation Reserve Program established in 1997 is targeted at enrolling the most environmentally sensitive land into the program. The program was capped by Congress at 36.4 million acres, meaning that only about 15% of eligible cropland could be enrolled. Land is evaluated and scored for environmental benefit, including: wildlife habitat enhancement, water quality benefits, reduced erosion, long-term retention benefits, air quality benefits, land's location in a Conservation Priority Area, and cost of enrollment per acre. The CRP attempts to maximize conservation and economic benefits by focusing on highly erodible land, riparian areas, cropped wetlands, and cropland associated with wetlands.

CRP in the Study Watersheds

A variety of conservation practices are currently in use in the study watersheds. Figure 10 shows the locations of filter strip areas, grassed waterways, and cropland enrolled in the CRP. Instead of farming the tracts, landowners have installed filter strips, grassed waterways, and wildlife set-asides in these areas. Table 13 contains acreages of land enrolled in the CRP and numbers of filter strips and grassed waterways for each subwatershed. The Lower Mud Pine Creek Subwatershed contains the only CRP designated farm in the study area. An estimated 152 acres of filter strips and 13,289 linear feet of grassed waterways have been constructed in the study watershed. In all, about 0.4% of the Upper Mud Pine Creek Watershed has been set aside either in the CRP or as filter strip areas.

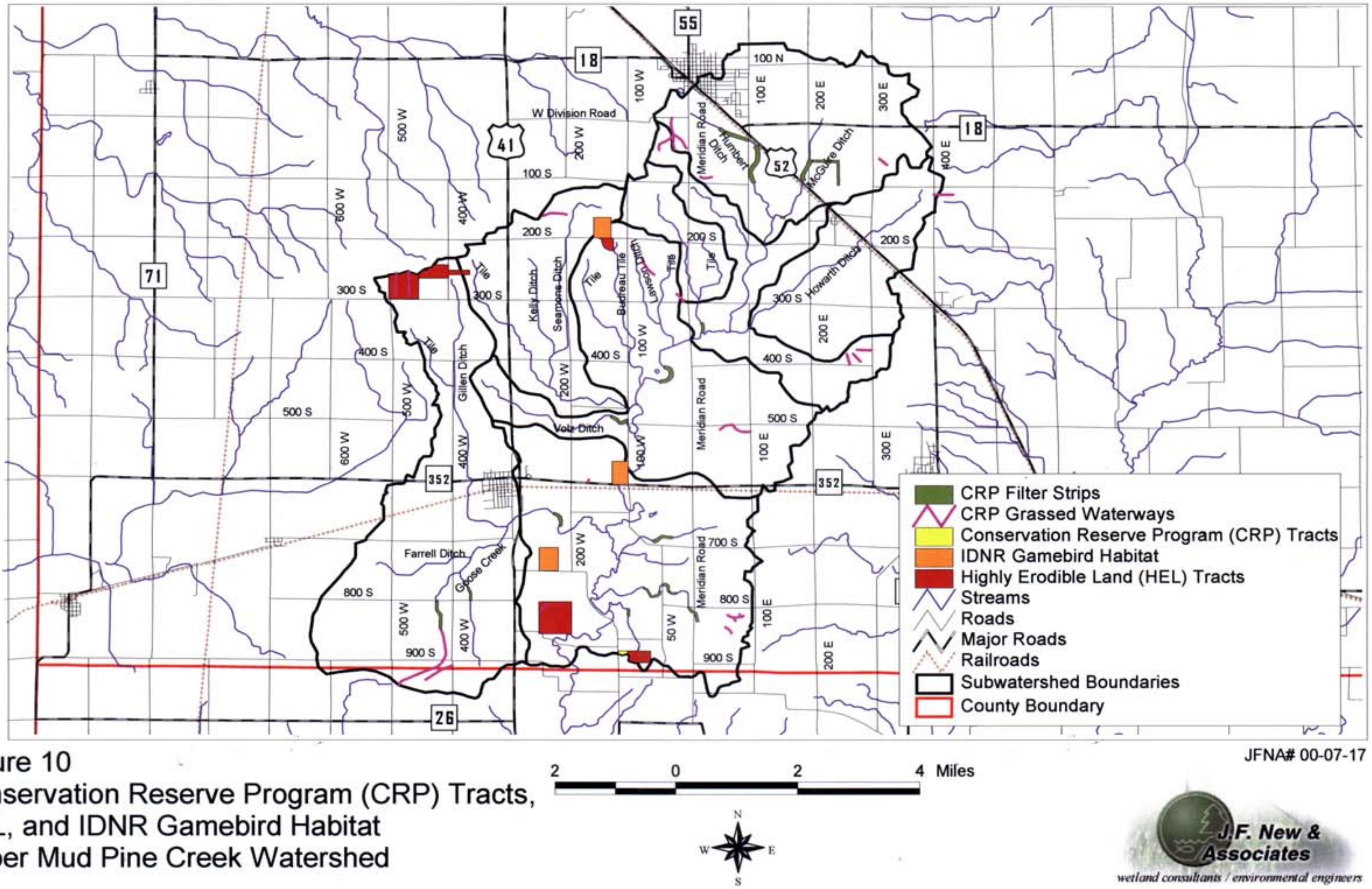

Figure 10
Conservation Reserve Program (CRP) Tracts,
HEL, and IDNR Gamebird Habitat
Upper Mud Pine Creek Watershed

TABLE 13. Acreages of land enrolled in the CRP and numbers of filter strips and grassed waterways by subwatershed. All area estimations are given in acres and all length estimates in feet.

Subwatershed	Area in CRP	Area in Filter Strips	Number of Filter Strips	Length of Grassed Waterways	Number of Grassed Waterways	% of Watershed in Conservation	HEL: CRP and Filter Strips
Humbert Ditch	0.0	69.0	4	448.5	1	1.18	0:0
Howarth Ditch	0.0	1.8	1	0.0	0	0.05	0:0
Wattles Ditch	0.0	0.0	0	154	1	0.00	0:0
Seamons Ditch	0.0	0.6	1	1,097	1	0.02	11.6:1
Upper Mud Pine Creek	0.0	0.0	0	1,693	3	0.00	0:0
Volz Ditch	0.0	29.8	2	2,735	3	0.42	0.8:1
Goose Creek	0.0	20.6	2	5,070	2	0.23	9.9:1
Lower Mud Pine Creek	5.3	29.8	4	2,093	6	0.42	6.7:1
Total	**5.3**	**151.6**	**14**	**13,289**	**17**	**0.38**	**3.0:1**

Source: Farm Service Agency of Benton County and Neil Deckard, personal communication.

A comparison of conservation set-asides and HEL designations can help to determine areas where management may be best targeted. The CRP farm in the Lower Mud Pine Creek Subwatershed overlaps with land that is also highly erodible (Figure 10); however, some watersheds contain HEL but not CRP. The small acreages of HEL within the Seamons Ditch, Volz Ditch, and Goose Creek are not treated with any CRP enrollment. In the Lower Mud Pine Creek Subwatershed, only one grassed waterway area exists to protect HEL. Humbert Ditch, Howarth Ditch, Wattles Ditch, and the Upper Mud Pine Creek Subwatersheds contain no HEL and also no CRP. Of the subwatersheds containing both HEL and conservation areas (CRP and filter strips), the Seamons Ditch (11.6:1) and the Goose Creek Subwatersheds (9.9:1) have the two highest HEL:conservation practice ratios. For the entire Upper Mud Pine Creek Watershed, every three acres of HEL is matched with one acre of conservation set aside. Based on the above analysis, future CRP enrollment and conservation efforts should focus on the HEL within the Goose Creek, Lower Mud Pine Creek, and Volz Ditch Subwatersheds.

Some non-protected HEL tracts directly border streams and tributaries to streams within the watershed. HEL tracts that adjoin streams are located in the Upper Mud Pine Creek and Volz Ditch Subwatersheds. These tracts would be optimal sites for CRP or other program enrollment.

In addition to CRP tracts, the IDNR has purchased several areas for gamebird habitat in the Upper Mud Pine Creek Watershed (Figure 10). These areas are conserved and managed for wildlife habitat according to Bob Porch, the IDNR wildlife biologist at Willow Slough. The Geswein Gamebird Habitat Area (80 acres in size) was acquired in 1994 utilizing gamebird habitat revenues. The Brouillette area offers 65 acres of habitat and was purchased in 1987 and 1991 with gamebird monies. The Hawkins reserve area is 60 acres in size and was paid for using gamebird habitat stamp revenues in 1987. Additionally, Mr. Porch stated that the IDNR cashrents several small areas in the watershed from farmers on a year-to-year basis for wildlife habitat. These areas are valuable conservation and recreation assets in the Mud Pine Creek Watershed.

Conventional Structural Conservation Practices

Introduction

Continuous sign-up is permitted through the CRP for special high-priority conservation practices that lead to significant environmental benefits. These practices are structural in nature and are specially designed to protect and enhance wildlife habitat, improve air quality, and improve waterway condition. These conservation practices and relevant research involving their use are discussed in more detail below.

Filter Strips

A filter strip is an area of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants from runoff. Filter strips slow the velocity of water, allowing settling of suspended particles, infiltration of runoff, adsorption of pollutants on soil and plant surfaces, and uptake of soluble pollutants by plants. Slower runoff velocities and reduced flow volumes lead to decreased downstream erosion.

A modeling study by Texas A&M University suggests that if filters were properly installed in all appropriate locations, sediment delivery to rivers and lakes could be reduced by two-thirds (National Conservation Buffer Council, 1999). Preventing sediment delivery to streams has important and significant economic ramifications. According to a study by the Ohio State University Extension Service, a 25% decrease in the amount of sediment entering waterways in the state would save $2,700,000 in water treatment costs per year (Leeds et al., 1997). The cost of dredging sediment out of these waterways was estimated at $1,500,000 per year for the state of Ohio. Additionally, buffer strips have been associated with healthier aquatic communities (Wiegel et al., 2000).

Typically, filter strips are planted on cropland at the lower edge of a field or adjacent to waterways. They are most effective when receiving shallow, uniform flow rather than concentrated runoff localized in channels or gullies. The Natural Resources Conservation Service (NRCS) recommends minimum filter strip widths based on intended purpose of the area (NRCS, 2000). The minimum flow length is set at 20 ft (6 m), but the minimum can be increased to 30 ft (9 m) based on sediment, particulate organic matter, and sediment-adsorbed contaminant loading in runoff. The average watershed slope above the filter strip must be greater than 0.5% but less than 10%. The NRCS standard is site-specific with plans and specifications required for each field site where a filter strip will be installed. It is important to keep in mind that effective filter strip width is also dependent on the amount of land draining into the filter. Ratios of the field drainage area to the filter area should be no greater than 50:1. Based on a survey of more than 2,700 CRP sites in the U.S., the ratio averaged approximately 3:1 (Leeds et al., 1993).

A wide variety of vegetation types have been used for planting filter strips. The ideal plant or combination of plants would be characterized as: native to Indiana, sod-forming, palatable as forage, somewhat cool season so as to grow early in spring when most runoff events occur, hardy, rapidly growing, tolerant of nutrient-poor conditions so as to not need fertilization, able to remain standing throughout the winter providing shelter for wildlife, and economical/affordable.

The use of plants native to Indiana is ecologically the most desirable alternative. (Please see the NRCS Conservation Practice Standard Code 393 for specifics and requirements regarding vegetation planting within filter strips (NRCS, 2000).) Advantages of planting native vegetation include: 1.) native species possess extensive rooting structures that hold soil and reduce erosion (Figure 11 depicts rooting depths of several native grass species); 2.) many types can be hayed for forage use, and in fact big bluestem and Indian grass as highly palatable for forage (Clubine, 1995); 3.) natives are hardy and able to withstand various hydrologic regimes; 4.) low maintenance and cost over the long-run due to natural re-seeding processes and hardiness; 5.) low nutrient demand so as to not require costly fertilization which can further impair water quality; 6.) native plants provide wildlife habitat by remaining standing through the winter; 7.) native wildflowers are beautiful, and their seeds can be added to mixes for aesthetic value; 8) some legume species like roundhead lespedeza, the prairie clovers, lead plant, and tickclovers are quite resilient to livestock grazing (Clubine, 1995).

Some disadvantages of establishing native herbaceous vegetation in filter strips also exist: 1.) most native grasses are warm season (except for red top and Virginia wildrye) and may not offer optimal nutrient uptake in early spring when many runoff events occur; 2.) some species have been reported to be difficult to establish and may take years for full stand development (Leeds et al., 1993); 3.) native wildflower plants and other forbs can be quite susceptible to herbicides used in crop production; 4.) many are quite expensive to produce (see tables below); 5) some native legume species like Illinois bundleflower have been shown to be susceptible to grazing (Clubine, 1995).

The following Tables 14-20 present lists of recommended native cool season grasses, legumes, and wildflowers. Information is also presented on species that are considered less than desirable as filter strip vegetation. Five different recommended mixes are provided along with seeding rates in lbs/acre and approximate costs according to the February of 2001 price listing of Sharp Bros. Seed Company of Missouri and the J.F. New Native Plant Nursery 2001 Wholesale Catalogue. Mixes should be chosen based on management application and available finances. Table 21 lists vegetation types that should not be used due to severe limitations. It is important to remember that a filter strip or conservation easement planted with any vegetation type is better than not having the easement at all. Even if optimal mixes are not chosen or applied, an individual's willingness to participate in a set-aside program will have positive effects for water quality.

It is also necessary to caution landowners who receive federal and/or state monies for planting vegetation. Certain programs may require special seeding mixtures. For example, CRP filter strips must be planted as per Tables 1 and 2 in the NRCS Conservation Practice Standard Code 393. The following eight tables give recommendations for landowners who may be purchasing their own seed or have received cost-share monies from programs that are more flexible with respect to seeding requirements.

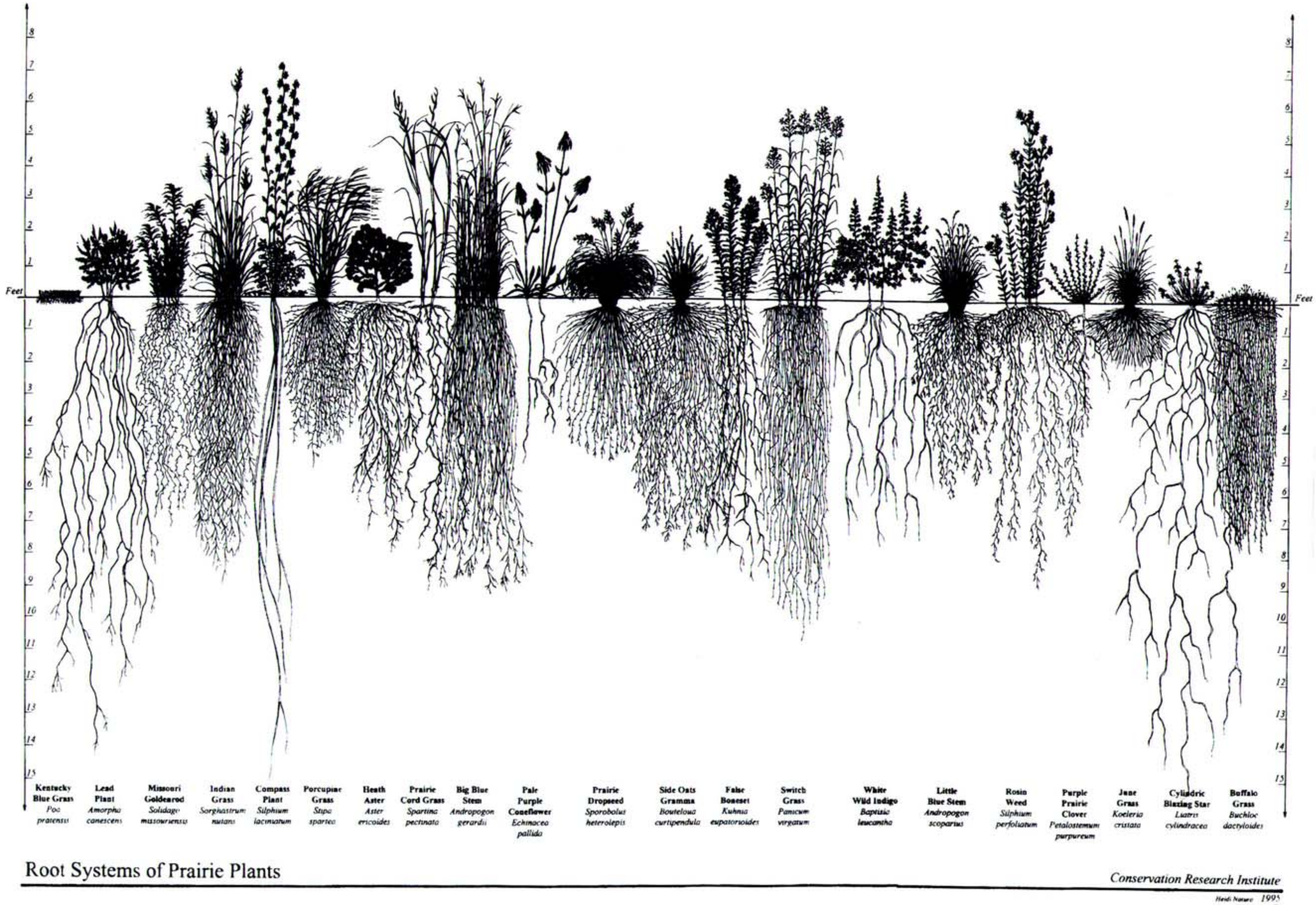

FIGURE 11. Rooting Depths of Native Grasses and Forbs.

TABLE 14. Recommended native cool season grass species and seeding rates (lbs/acre) for filter strip planting with price/lb per Sharp Bros. Seed Company of Missouri as of February, 2001.

Species	Seeding Rate	Price/lb
Red top	4 lbs/acre	$3.40
Virginia wildrye	4 lbs/acre	$6.90

* If seeding both together, use 2.5 lbs/acre of each.

TABLE 15. Recommended native legume species and seeding rates (lbs/acre) for filter strip planting with respective prices/lb.

Species	Seeding Rate	Price/lb
Roundhead lespedeza	0.25 lbs/acre	$98.00
Partridge pea	0.25 lbs/acre	$16.10
Illinois bundleflower	0.25 lbs/acre	$6.90
Purple prairie clover	0.25 lbs/acre	$23.00

* These forbs should be sown with native grass seed mixture.

TABLE 16. Recommended native wildflower species for filter strip planting with respective prices/lb.

Species	Price/lb
Black-eyed susan	$22.50
Lanceleaf coreopsis	$27.00
White prairie clover	$137.50
Ashy sunflower	$55.50
Pale purple coneflower	$108.90
Pitcher sage	$72.00
Compass plant	$99.00
Rosinweed	$74.25
Leadplant	$99.00
Purple coneflower	$29.70
Rattlesnake master	$99.00

* These native wildflowers can be seeded in small quantities (<0.25 lbs/acre) along with recommended seeding of native grasses.

TABLE 17. Optimal seed mix for filter strip seeding. This mix is considered optimal based on water quality and soil protection benefits, habitat management benefits, and economy/affordability. Six species are included plus a mix of wildflowers for a total seeding rate of 5.25 lbs/acre.

Species	Seeding Rate
Big bluestem	1.3 lbs/acre
Indiangrass	1.5 lbs/acre
Little bluestem	1.5 lbs/acre
Sideoats grama	0.5 lbs/acre
Switchgrass	0.2 lbs/acre
Mixed wildflowers	0.25 lbs/acre
TOTAL PRICE	**$64.25/acre**

* Virginia wildrye and red top can be seeded with the above mixture to increase cool season growth. Virginia wildrye should be seeded at 1 lb/acre and red top at 2 lbs/acre.

TABLE 18. Economy mix for filter strip seeding. This mix also offers native grass species at a more affordable cost. Only three species are included for a total seeding rate of 4.0 lbs/acre.

Species	Seeding Rate
Big bluestem	1.0 lbs/acre
Indiangrass	1.0 lbs/acre
Little bluestem	2.0 lbs/acre
TOTAL PRICE	**$49.90/acre**

* Virginia wildrye and red top can be seeded with the above mixture to increase cool season growth. Virginia wildrye should be seeded at 1 lb/acre and red top at 2 lbs/acre.

TABLE 19. Ultra economy mix for filter strip seeding. This mix offers only one native grass species at the most affordable cost. It is recommended that Virginia wildrye and red top be seeded with the switchgrass to increase species and habitat variety and to increase cool season growth in the filter strip.

Species	Seeding Rate
Switchgrass	5 lbs/acre
TOTAL PRICE	**$15-20 lbs/acre depending on variety selected**

TABLE 20. Wildlife habitat management seed mix for filter strip planting or for other areas where managing prairie-type habitat for wildlife is desirable. The total cost for 51.5 lbs for seeding of one acre is $450.00 (J.F. New Native Plant Nursery Wholesale Catalogue, 2001). The temporary grasses serve only to stabilize soils and provide habitat until the permanent, perennial grasses fully develop.

Species	Seeding Rate
Permanent Grasses	5 lbs/acre
Big bluestem	
Little bluestem	
Sideoats grama	
Virginia wildrye	
Switchgrass	
Temporary Grasses	44 lbs/acre
Seed oats	
Annual rye	
Timothy grass	
Native Forbs	2.5 lbs/acre
Butterfly milkweed	
New England aster	
Partridge pea	
Sand coreopsis	
Purple coneflower	
False sunflower	
Rough blazing star	
Wild lupine	
Yellow coneflower	
Black-eyed susan	

TABLE 21. Plant species that are generally not good candidates for use in filter strips and reasons for their unsuitability. The reasons listed in the table represent the opinions of botanists at J. F. New and Associates, Inc. and are based on scientific literature, experience and observation, and rooting philosophy information.

Species	Reason for Insuitability
Birdsfoot trefoil	poor rooting structure with little ability to stabilize soil
Smooth brome	poor rooting structure with little ability to stabilize soil
Fescue	poor rooting structure with little ability to stabilize soil
Japanese millet	poor rooting structure with little ability to stabilize soil
Orchardgrass	poor rooting structure with little ability to stabilize soil
Reed canarygrass	poor rooting structure with little ability to stabilize soil; invasive; excludes other more beneficial vegetation; no wildlife habitat benefit
Crownvetch	poor rooting structure with little ability to stabilize soil; invasive
Kentucky bluegrass	very shallow root system; invasive; excludes other more beneficial vegetation; no wildlife habitat benefits
Perennial rye	invasive; excludes other more beneficial vegetation
Red clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive
White clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive

Filter strip effectiveness has been the subject of voluminous recent research. Most research indicates that filter strips are effective at sediment removal from runoff with reductions ranging from 56-95% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999). Most of the reduction occurs within the first 15 feet (4.6 m). Smaller additional amounts are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrient concentration like those of nitrate, dissolved phosphorus, atrazine, and alachlor, although reductions of up to 50% have been documented (Conservation Technology Information Center, 2000). Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Filter strip age is an additional factor of importance for effective function. Schmitt et al. (1999) found older grass plots (25 yr-old) to be more effective filters than recently planted ones (2 yr-old). A longer amount of time was required for runoff to reach the outfall of the older plots, suggesting that a strip's ability to slow runoff and filter pollutants increases with age.

Filter strips are effective in reducing sediment and nutrient runoff from feedlot or pasture areas as well. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen, and approximately 67% of the phosphorus from feedlot runoff. In addition, they found a 67% reduction in runoff volume. However, it is important to note that filter strips should be used as a component of an overall waste management system and not as a sole method of treatment.

Filter strips, like all conservation practices, require regular maintenance in order to remain effective. Maintenance consists of: 1) inspection of the project frequently, especially after large storm events; 2) repairing and reseeding of any areas where erosion channels develop; 3) reseeding of bare areas; 4) mowing and removing hay to maintain moderate vegetation height while not mowing closer than 6 inches. To avoid destruction of wildlife nesting areas, delay mowing until after mid-July; 5) controlling trees, brush, and noxious or invasive weeds within the filter; 6) applying fertilizer and lime at rates suggested by regular soil testing.

Riparian Buffers

In many ways similar to filter strips, riparian buffers are streamside plantings of trees, shrubs, and grasses intended to intercept pollutants before they reach a river or stream. Although comparisons reveal that riparian buffers are no better than grassed strips at retaining nutrients and sediment, they offer shade and cover to the stream, thereby providing valuable fish and wildlife habitat (Daniels and Gilliam, 1996). Due to their deeper rooting systems, riparian buffers can filter both surface and subsurface runoff before it reaches the waterway. The rooting systems of riparian buffers can also serve to stabilize banks and soils especially along ditches that pass through mucky or easily erodible soil.

Field Borders

Field borders are 20-ft wide filter strips or bands of perennial vegetation planted at the edge of fields that can be used as turning areas for machinery. They also provide wildlife cover, protect water quality, and reduce sheet, rill, and gully erosion. Borders should be repaired and reseeded after storms and should be mown and harvested in the late summer to early fall to encourage growth for the next spring.

Shelterbelts/Windbreaks

Shelterbelts are rows of trees, shrubs, or other vegetation used to reduce wind erosion and protect crops while also providing protection for wildlife, livestock, houses, and other buildings. Similar to shelterbelts, windbreaks or hedgerows are located along crop borders or within fields themselves. Air quality improvement and wildlife habitat provision are the greatest benefits of these vegetation belts.

Grassed Waterways

Grassed waterways are natural or constructed channels that are seeded with filter vegetation and shaped and graded to carry runoff at a non-erosive velocity to a stable outlet and vegetated filter. Vegetation in the waterway protects the topsoil from erosion and prevents gully formation, while providing cover for wildlife. The stable outlet is designed to slow and spread the flow of water and direct it towards the vegetated filter.

Grassed waterways are typically used where water tends to concentrate, like in draws, washouts, or other low-lying gully areas. They can also be used as outlets from other conservation practices (like terraces) or in any other situation where a stable outlet and vegetated filter can be built and maintained.

These vegetated filter systems may be trapezoidal or parabolic in shape, but should be broad and shallow in construction. They should be able to carry the runoff of a 10-year storm event. The stable outlet should be planted with perennial, sod-forming grasses to provide a dense filter. The vegetated filter below the outlet should be constructed as a typical filter strip would be.

Proper operation and maintenance is necessary for effective grassed waterway function. Tillage and crop row direction should be perpendicular to the waterway to allow drainage and to prevent water movement along edges. Machinery crossing areas should be stabilized to prevent damage to the waterway. Vegetation within the filter should be protected from direct herbicide applications. Certain species may be more tolerant of certain herbicide chemicals. It is also important to keep the strip and its outlet as wide as is possible. The waterway may need reconstruction from time to time to maintain proper shape.

Shallow Water Areas

Shallow water areas within or near farmland provide cover and a water source for wildlife while also acting as a filter. Embankments and berms that pond water increase the land's water storage capacity helping to reduce volumes and flow rates of runoff. Constructed wetlands contribute to water quality improvement by: 1) reducing coliform bacteria by 90% (Reed and Brown, 1992); 2) fostering growth of microbes that recycle and retain nutrients (Wetzel, 1993); 3) providing additional adsorption sites for nutrients through the decomposition of organic matter (Kenimer et al., 1997); 4) providing anaerobic areas where denitrification processes can release nitrogen to the atmosphere; 5) degrading organic materials thereby decreasing biological oxygen demand (BOD); 6) offering sedimentation and filtration processes which remove suspended solids and adsorbed nutrients; and 7) providing flood water storage to attenuate peak flood flows.

Wellhead Protection Area

Wellhead protection areas help assure the quality of public water supplies drawn from wells. Continuous CRP enrollment is available for land within a 2000-ft radius of a public well. Vegetation planted in these areas can further help prevent water supply contamination.

Cover Crops

The use of cover crops prevents soil from being bared through the winter and early spring months when some of the most pronounced runoff events may occur in Indiana. Cover crops reduce surface runoff by as much as 50% due to increased infiltration (Unger et al., 1998). Reductions in both the dissolved and particulate forms of nitrogen and phosphorus have also been documented.

Other Conventional Structural Conservation Practices

A wide variety of other conventional structural conservation practices have been prescribed and are in use in various areas of the county. Although not all practices are applicable in every situation, systems of two or more structural BMPs used in concert are often required to achieve the desired conservation benefit. A complete listing of the over 160 different conservation practices recognized by the USDA is available online at http://www.ncg.nrcs.gov/nhcp_2.html. The website offers standards and more details for each practice in a portable document format (PDF) and in MS-Word format. Structural conservation practices that are relevant for use in the Upper Mud Pine Creek Watershed are listed in Appendix 2.

Conventional Managerial Conservation Practices

Introduction

Managerial BMPs are those that involve behavior or decisions made with respect to normal land use operation. Commonly used practices include conservation tillage, rotational grazing, and pesticide management. Managerial conservation practices are often less expensive because they don't involve building a structure; however, successful implementation may require a changing of habitual behaviors and some trial and error experimentation. Several commonly used managerial practices are discussed below.

Conservation Tillage

Introduction

Removal of land from agricultural production may not be economically feasible in some cases. Conservation tillage offers the potential for reducing erosion without removing the land from production. Conservation tillage is a crop residue management system that leaves at least one-third of the soil covered with crop residue after planting. Table 22 offers description of the different tillage types. No-till, ridge-till, and mulch-till are all examples of conservation tillage.

Aside from valuable time-saving for the producer, a comprehensive comparison of tillage systems shows that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (CTIC, 2000). Figure 12 illustrates calculations of soil loss with respect to the "tolerable" amount of soil that can be lost while still maintaining the productivity of the soil through natural formation processes. On average, all tillage methods exceed the T value for Indiana soils; however, soil loss is less using no-till and mulch tillage. Reductions in pesticide loading have also been reported (Olem and Flock, 1990). In his review of Indiana lakes, Jones (1996) documented lower Trophic State Index (TSI) scores in ecoregions with higher percentages of conservation tillage. A TSI is a score that condenses water quality data in a single, numerical index. Higher scores indicate evidence of eutrophication (overproductivity) and poorer water quality. No-till practices are also good for wildlife. North Carolina researchers have found that crop residues provide the food that quail chicks need to survive the first few weeks of life. Additionally, conservation tillage reduces carbon dioxide emissions from the soil. Carbon dioxide, the most ubiquitous of the greenhouse gases, is being found at ever-increasing concentrations in the atmosphere and has been linked to global warming.

TABLE 22. Tillage type descriptions.

Type	Description	% Remaining Residue	Conservation Tillage Type?
No-till/strip-till	soil is undisturbed except for strips up to 1/3 of the row width	>30%	Yes
Ridge-till	4-6" ridges are formed on strips up to 1/3 of the row width	>30%	Yes
Mulch-till	full width of the row is tilled using only one or two tillage passes	>30%	Yes
Reduced-till	full width of the row is tilled using multiple tillage passes	16-30%	No
Conventional-till	full width of the row is tilled using multiple tillage passes	<15%	No

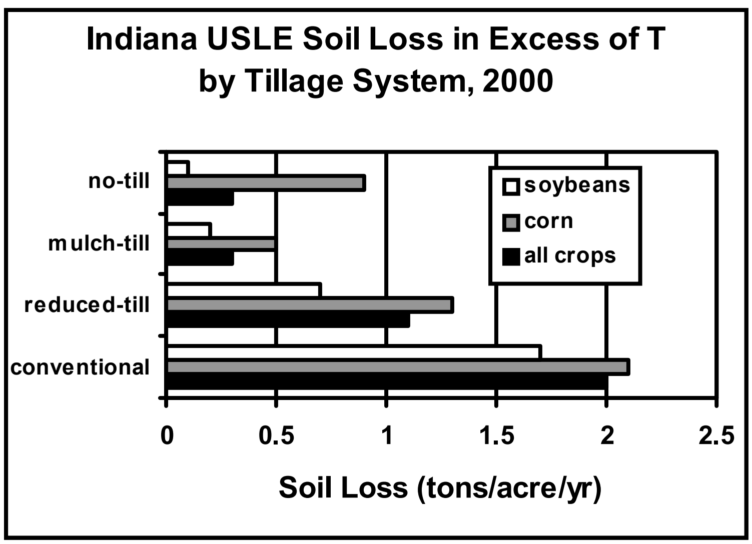

FIGURE 12. Indiana average USLE soil loss in tons/acre in excess of T by tillage system for 2000. USLE is the Universal Soil Loss Equation. Values shown are in excess of T, which is the "tolerable" amount of soil that can be lost while maintaining the productivity of the soil. Most Indiana soils have a T-value of 3-5 tons per acre per year. Source: Clean Water Indiana Education Program, Purdue University.

Agricultural economists with the Ohio State University Extension have reported that farmers adopting conservation tillage in the Maumee and Sandusky River Watersheds saw modest decreases in farm production costs (Agrinews, 2001). During that same time period, monitoring data showed decreased loading to Lake Erie of many non-point source pollutants that are related to farming. The researchers reported individual farm savings of 2-8% in labor costs and 6-15 percent in machinery operation costs; however, farmers adopting no-till practices did incur a 10-18% increase in herbicide costs due to lack of tillage for mechanical weed control.

While conservation tillage has been shown to reduce total phosphorus and total nitrogen in surface runoff by as much as 70 and 75% respectively, increased dissolved phosphorus and nitrate losses have been documented (Sharpley and Smith, 1994). In the Sharpley and Smith (1994) study, nitrate concentrations were increased from 4.5 to 29 mg/l and dissolved phosphorus concentrations were 300% higher. The increase in nitrate was attributed to increased infiltration that occurs with conservation tillage. Higher phosphorus concentrations were attributed to leaching of the nutrient from crop residue and preferential transport of smaller-sized soil particles that is associated with no-till practices. Another study by the Ohio State University Extension also documented 10-15% increases in nitrate runoff to local streams (Indiana Agrinews, 2001) and suggested that conservation tillage time savings allowed farmers to substitute winter wheat planting with corn, requiring higher amounts of nitrogen fertilizers.

Tillage Patterns in the Upper Mud Pine Creek Watershed

While conservation tillage patterns were not estimated for the study watershed, they are in use throughout Benton County and on many fields within the watersheds. Table 23 shows conservation tillage usage patterns in the growing season of 2001 for Benton County.

TABLE 23. Percent (number) of crop fields with indicated tillage system in the growing season of 2001 for Benton County. N/A refers to those fields where tillage was not performed as in the second year or later of hay, fallow fields, and fields in CRP.

Crop	No-till	Ridge-till	Mulch-till	Reduced-till	Conventional-till	N/A
Corn	19 (48)	0 (0)	28 (71)	42 (106)	11 (29)	0 (0)
Soybeans	62 (156)	0 (0)	33 (83)	4 (11)	1 (2)	0 (0)
Small Grain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (1)
Hay/Forage	0 (0)	0 (0)	0 (0)	0 (0)	20 (1)	80 (4)
Fallow/Other	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (1)

Source: Purdue Cooperative Extension Service, 2001.

Producers in Benton County produced most of their corn and soybean crops using a conservation tillage method. For soy beans, no-till was the most commonly used tillage technique, while reduced-till was the most commonly used for raising corn. Mulch-till was also used somewhat frequently for both crops. Only one field was used to grow small grain and five fields produced hay in 2001. Of the 92 counties in Indiana, Benton County ranked 43rd and 51st for percent of corn and soybeans, respectively, planted using a no-till system in 2000 (Evans et al., 2000).

In 2000, conservation tillage was used on 45% of Indiana's cropland. Even though Indiana is a no-till leader among cornbelt states, data suggest that few fields were no-tilled over the long term. Given that most research suggests that no-till benefits to soil begin to appear no earlier than the 3rd consecutive year of no-till, many farmers are abandoning no-till at about the time one would expect its benefits (Evans et al., 2000). Data from the Purdue Agronomy Research Center suggest that over the past 25 years, no-till used in a corn-soybean rotation economically outperformed conventional, mulch, and strip tillage systems (West et al., 1999). Producers should be encouraged to give no-till practices the continuous time necessary to reap yield, economic, and environmental benefits. Hanson Young of the Noble County Purdue Cooperative Extension Agency expects conventional/full tillage in northern Indiana to be dramatically increased in 2002 due to rill and gully erosion problems induced by the unusually wet October of 2001.

Producers that switch to a conservation tillage pattern should keep in mind that the normal planting process and management regime may need to be modified or "fine-tuned" for success. Tillage will no longer destroy weeds before planting, and new weed species will invade given the different soil conditions. Treating these new invaders may require different herbicides. Certain crop varieties may not tolerate the change in herbicide regime, so a different crop variety may be required. Yield reduction which at first may be associated with tillage change may be due in fact to a different level of tolerance to a new herbicide (Canada-Ontario Green Plan, 1997).

Nutrient Management

Nutrient Management Research

Nutrient management has been the focus of agricultural research in many parts of the country. Studies have shown that every year about 15% of the applied, 68 % of the residual in the non-root zone layer, and 20% of the residual nitrogen in the root zone layer are deposited to the ground water (Yadav, 1997). To address this concern, the Penn State Cooperative Extension Service designed a nutrient management plan based on: 1) crop yield goals; 2) soil type; 3) methods of manure and commercial fertilizer application; 4) nitrogen concentrations in soils; 5) nitrogen concentrations in manure to be used for fertilizer; 6) crop rotations (Hall and Risser, 1993). With this plan in place: 1) fertilizer application as manure and commercial fertilizer decreased 33% from 22,700 lbs/year to 15,175 lbs/year; 2) nitrogen loads in groundwater decreased 30% from 292 lbs of nitrogen per 1,000,000 gal of groundwater to 203 lbs per 1,000,000 gal; and 3) the load of nitrogen discharged in groundwater was reduced by 11,000 lbs for the site over a three-year period (70 lbs/ac/yr).

Nutrient Management in the Study Watershed

Like many agricultural areas, fertilization is an important part of production in the study watersheds. Producers in the watershed area generally apply potash in the fall and anhydrous ammonia during the spring at planting (Cedric Durkis of the Benton County Purdue Cooperative Extension Agency (PCEA). Some producers also apply nitrogen in the fall when corn is planted after soybeans in the crop rotation. There are few animal operations in the area, so little hay is grown, and manure is not a typically applied as fertilizer. Mr. Durkis estimates that there is only one dairy in all of Benton County and one sheep operation.

Management of nutrients applied in fertilizer can greatly benefit water quality. The first step in effective nutrient management is regular soil testing. Historically, producers have conducted soil tests only when a problem is noticed. More recently, soil testing once every 3-5 years has become more common among grain producers (Hanson Young of the Noble County Purdue Cooperative Extension Agency, personal communication). According to Cedric Durkis, in general one-third of every tract used for production is tested each year in the Upper Mud Pine Creek Watershed resulting in soil sampling of the entire tract once every three years. Soil tests typically include detection of soil phosphorus, potassium, lime content, pH, and nitrogen, and fertilizer companies are typically hired to collect the samples and conduct the analyses.

Fertilizer should be applied based on realistic yield goals, and Cedric Durkis believes that most farmers in the area fertilize based on a realistic expectation of 160-175 bushels/acre when an optimal expectation may be around 220 bushels/acre. Farmers also typically reapply fertilizer based on the amount estimated to have been removed with the previous year's crops. Producers should also make allowances in nitrogen applications for N contributions of any previous legume crops in the rotation or any legume cover crops. Durkis stated that most farmers in Benton County use a soy-corn rotation and do account for legume N-addition in their fertilizer regimes. In fact, most producers use little if any nitrogen when soybeans will be planted on a field that produced soybeans the year prior. Fertilizer regimens are typically reduced by 20-30 pounds/acre when corn is to be planted after soybeans in the rotation. Fertilizer adjustment may also be necessary when transitioning from conventional to conservation tillage.

In special areas of environmental concern, such as fields that border streams and other waterbodies, fertilizer setbacks should be utilized. Setbacks are strips or borders where fertilizer is either not applied or applied in smaller quantities. Fertilizers should not be applied directly next to streams and certainly not in them. According to the Benton County Purdue Cooperative Extension Agency, fertilizer setbacks are widely used, and most farmers do not apply fertilizer within 66 feet of open ditches. Although Mr. Durkis stated that the land has little topography and therefore, little highly erodible land, he does feel that producers on the few highly erodible tracts and in other areas of environmental concern do tend to be more conscientious with respect to fertilizer application. According to Durkis, most farmers do "a pretty good job" at being environmentally responsible.

Though not a nutrient in and of itself, *E. coli* bacteria contamination of waterways is an indirect effect of applying animal waste as fertilizer. *E. coli* and other bacteria from the intestinal tracts of warm blooded animals can cause gastroenteritis in humans and pets. Symptoms of gastroenteritis include: nausea, vomiting, stomachache, diarrhea, headache, and fever. Due to high *E. coli* counts, about 81% of the assessed waters in Indiana did not support "full body contact recreation" in 1994-1995 (IDEM, 1995). Even though few animal operations exist in the watershed, farmers that do apply manure can take precautionary step to ensure that bacteria and nutrients from manure do not contaminate stream and ditches. To prevent manure from entering tiles, ditches, and streams, producers can: 1) apply manure at optimal times for plant uptake; 2) apply when potential for plant uptake is high and runoff is low; 3) inject or incorporate manure to reduce runoff potential; 4) use filter strips; and 5) use setbacks from surface inlets to tile lines.

Weed and Pest Management

Weed and Pest Management Research

Ground water data assembled by the U.S. Geological Survey (USGS) and the Environmental Protection Agency (EPA) found 18 pesticides and five pesticide breakdown products in 9% of the samples taken in Indiana (Goetz, 2000). Modeling by Purdue University professor Bernie Engel, showed that 75% of detectable pesticides in groundwater came from 25% of farmland. Using his data, Dr. Engel created a pesticide leaching risk map (Figure 13) and helped the State write the Indiana State Pesticide Management Plan that is available on-line at http://www.isco.purdue.edu/psmp/oiscmain.html.

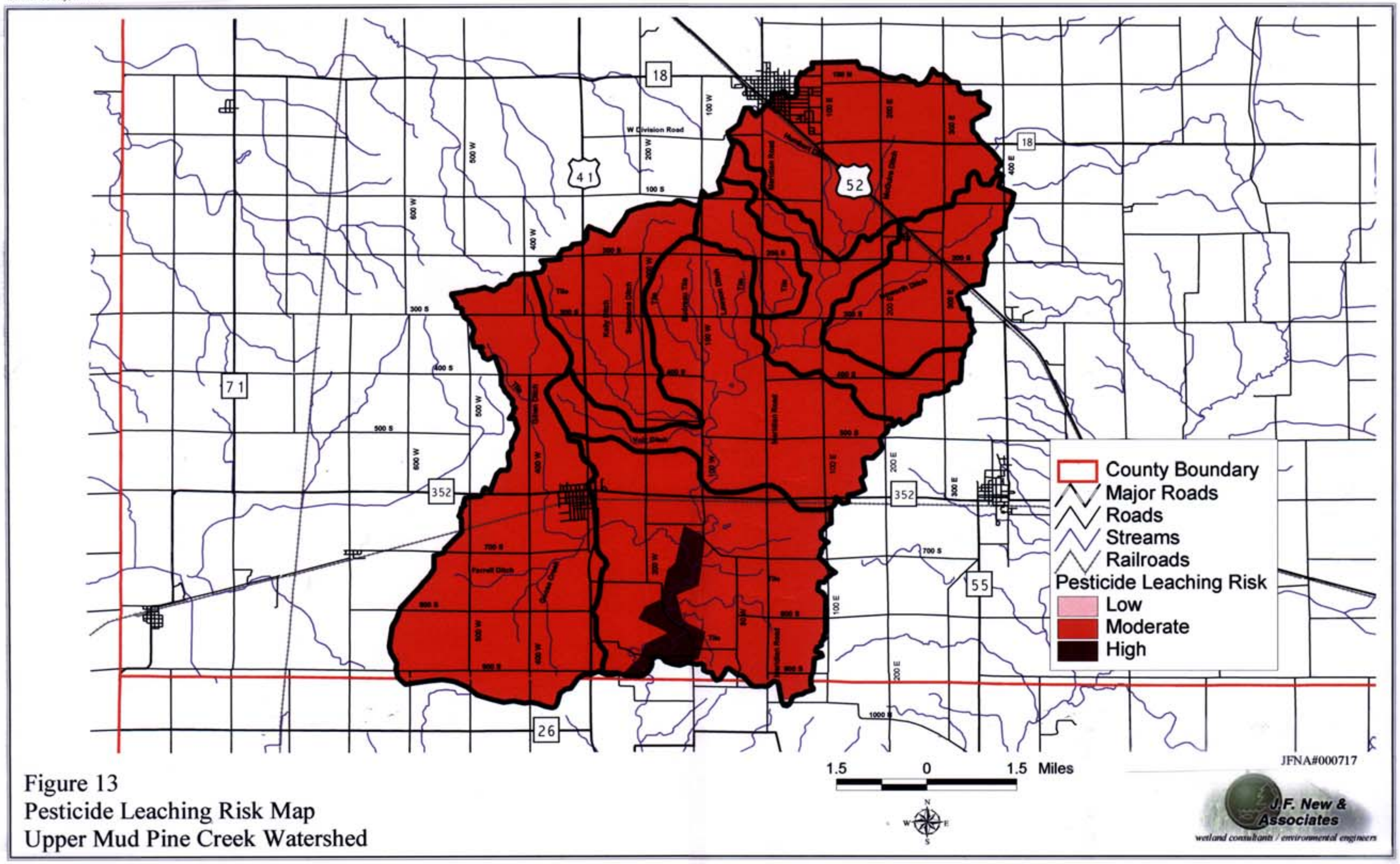

Figure 13
Pesticide Leaching Risk Map
Upper Mud Pine Creek Watershed

Weed and pest management results in fewer herbicide and pesticide applications at reduced rates and thereby helps to protect the environment by reducing polluted runoff. Proper management of these chemicals entails: 1) being familiar with the threshold at which weed and pest populations begin to cause economic damage; 2) using local weather forecasting to time field scouting to determine if pest problems are great enough to warrant the use of a control measure; 3) planting cover crops to suppress weed growth; 4) planting seed that has been bred for pest resistance during optimal conditions; 5) using insect traps near target crops to track infestations; 6) promoting and attracting natural enemies that help control pests; 7) applying the most effective and appropriate pesticide or herbicide during optimal weather conditions.

Properly functioning tile lines have been shown to reduce pesticide contamination of water by: 1) decreasing runoff so less pesticide is carried in water and 2) when water runs through the soil on its way to tiles, many of the chemicals are adsorbed by soil particles (Goetz, 2000). In fact, compared to pesticide runoff in surface water, relatively little soaks down through the soil into the ground water (Kladivko, 1999). Although it may vary with soil type, the amount of pesticide that enters tile lines is generally less than half a percent of the amount applied. Meanwhile, surface runoff from poorly drained fields during the first or second storm after application can contain 1-2% of the pesticide applied. Based on her research Purdue agronomy professor Eileen Kladivko recommends that farmers properly tile poorly drained fields if they are to be used for production to avoid possible surface water contamination with pesticides (Goetz, 2000).

Weed and Pest Management in the Study Watershed
In the Upper Mud Pine Creek Watershed, herbicides are applied just before planting with follow up treatments as needed; pesticide is also applied at planting time after which further application is not usually necessary (Cedric Durkis). Because rootworm is the predominant problem pest in the study area, the pesticide is applied directly to the rows. Most farmers do their own insect scouting periodically during the growing season. Cedric Durkis also noted that insect problems are not prevalent in the area, and most of the time problems are so minor that economic losses due to crop depredation are too small to justify the cost of spraying. However, producers that grow alfalfa for animal food often have alfalfa weevil problems that do require spraying. Interestingly, an additional advantage of crop rotation (which is avidly used within the area) helps to break the annual life cycles of most typical crop insects (Jeff Burbrink of the Elkhart County Purdue Cooperative Extension Service, personal communication).

Resource Management Planning
Resource management planning is an individually based natural resource problem solving and management process advocated by the NRCS (NRCS, 2001). It addresses economic, social, and ecological concerns to meet both public and private needs while emphasizing desired future conditions. NRCS personnel work directly with landowners to understand his or her objectives to ensure that all parties understand relevant resource problems and opportunities and the effects of decisions. The process has three phases and nine steps:

Phase I – Collect and Analyze

1. Identify Problems and Opportunities
2. Determine Objectives
3. Inventory Resources
4. Analyze Resource Data

Phase II – Decision Support
5. Formulate Alternatives
6. Evaluate Alternatives
7. Make Decisions

Phase III – Application and Evaluation
8. Implement the Plan
9. Evaluate the Plan

Though not widely used, Resource Management Plans have met with success in most areas. According to Doug Nusbaum, an agriculture conservation specialist with the Indiana Department of Natural Resources (IDNR), most if not all fields (including highly erodible ones) can be responsibly managed and used for production with the development of a Resource Management Plan. Planning involves inventorying the resources, communicating with the landowner about where improvements may be made, and implementing the plan.

Other Conventional Managerial Conservation Practices

The USDA has published specifications for management-oriented practices in addition to the more common ones described above. Again not all practices are applicable in every situation, but managerial BMPs used in concert with structural BMPs are often required to meet conservation goals. A list of the various different conservation practices recognized by the USDA is available online at http://www.ncg.nrcs.gov/nhcp_2.html. Managerial conservation practices that are relevant for use in the Upper Mud Pine Creek Watershed are listed in Appendix 2.

Innovative/Newly Developed Conservation Practices

Introduction

Researchers interested in agriculture and conservation are testing new ideas for production management every day in the U.S. and Canada. A comprehensive literature search was conducted as part of the current study. BMPs that may present promise of benefit in certain situations are presented below. It should be noted that some of the practices have been developed fairly recently, and successful results cannot yet be guaranteed.

Riparian Management System Model

The Agroecology Issue Team of the Leopold Center for Sustainable Agriculture and the Iowa State University Agroforestry Research Team banded together in the early 1990s to promote restoration of the Bear Creek Watershed in central Iowa via development of a riparian management system model. Results of their study provide valuable lessons relative to management decisions and practices in the Upper Mud Pine Creek Watershed. The purpose of the study was to design a management system composed of several parts so that each part could be modified individually to meet site conditions and landowner objectives. Specific goals of the management system include: interception of eroding soil and agricultural chemicals, slowing of flood waters, stabilization of streambanks, and provision of wildlife habitat and an alternative, marketable product (Isenhart et al., 1997). The system model consists of a multispecies riparian buffer, streambank stabilization, a constructed wetland, and a rotational grazing strategy (Figure 14).

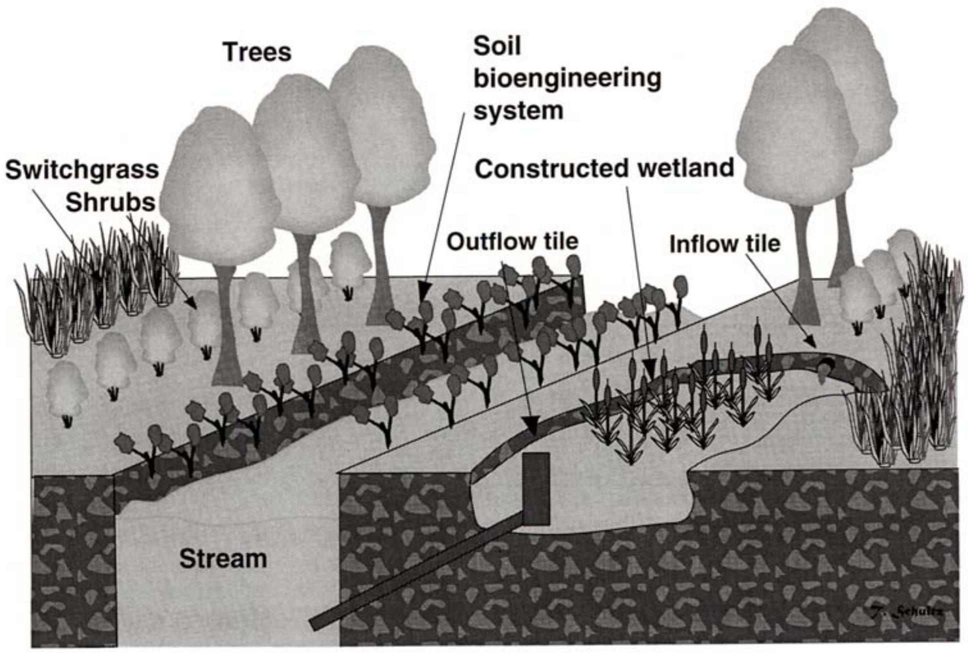

FIGURE 14. The riparian management system model (Isenhart et al., 1997). Used with permission from the American Fisheries Society.

The riparian buffer strip component consists of three zones (Figure 15): 1) A 33-foot-wide strip of trees bordering the stream. Fast-growing, native species like green ash, willow, poplar, and silver maple are recommended. Slower-growing trees like oaks and walnuts may be planted in the outer edge if desired. 2) A 12-foot-wide strip of shrubs. Shrubs, like trees, have permanent rooting structures and offer habitat diversity. Recommended species include ninebark, redosier and gray dogwood, chokeberry, witch hazel, nannyberry, and elderberry. 3) A 21-foot-wide strip of warm-season grasses. Species mixes were discussed in the filter strip section. Altogether the strip is 66 feet wide, but each component may be altered to address landscape requirements, desired buffer physical and/or biological functions, landowner objectives, and cost-share program standards. Appendix 3 includes before and after pictures of a riparian management system installation site in the Bear Creek Watershed.

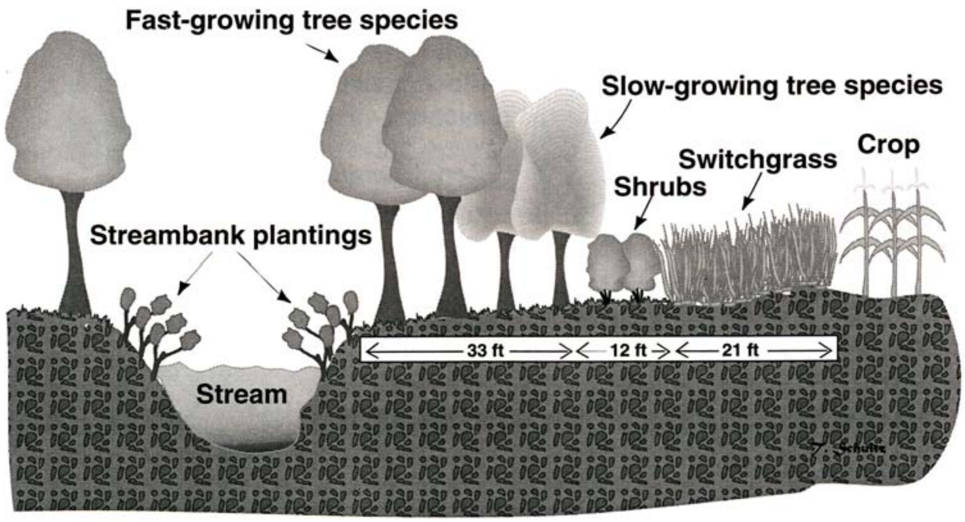

FIGURE 15. The multispecies riparian buffer strip component of the management system model. Used with permission from the American Fisheries Society.

Streambank stabilization using soil and vegetation bioengineering techniques is the second component of the comprehensive riparian management system model. Feasible techniques include installation of native, live plant material in combination with revetments of rock or wood and biodegradable erosion control fabric. According to Klingeman and Bradley (1976) bank vegetation provides a list of stabilization benefits: 1) plant roots hold soils together and in place; 2) above-ground vegetation increases surface flow resistance, decreasing flow velocities and routing energy dissipation toward plant material and away from soils; 3) vegetation buffers the channel from abrasion by materials transported from upstream; 4) vegetation induces sediment deposition, helping to keep soil on the land and to rebuild streambanks.

The final two components of the model include a constructed wetland designed to fit into the 66-foot buffer strip and a rotational grazing system to control livestock stream access. Constructed wetlands have a known track record for nitrate removal (via the process of denitrification) from surface water. In the Iowa study, water from a 12-acre field was tiled into a 2,900 ft^2 (<0.10 acre) wetland. A gated tile at the outlet of the structure provides control of water levels (Figure 14). Vegetation was planted in the wetland to jump-start nutrient uptake (See Appendix 3 for photo and Table 24 for a list of plants recommended for wetland planting). Other studies suggest that a wetland area to cultivated crop area ratio of 1:100 will provide the adequate water retention time during normal runoff events necessary to remove significant nitrate amounts.

TABLE 24. Plant species suitable for filtration and nutrient uptake in restored or created wetlands.

Grasses	Forbs
Redtop	Sweet flag
Creeping bent grass	Common water plantain
Spike rush	Cardinal flower
Common rush	Great blue lobelia
Rice cut grass	Monkey flower
Soft-stem bulrush	Arrow arum
Bur reed	Smartweed
Temporary Grasses	Pickerel weed
Seed oats	Broad-leaf arrowhead
Annual rye	

*** Seed the permanent grasses at 3 lbs/acre, the temporary grasses at 42 lbs/acre, and the forbs at 2.75 lbs/acre.**

An important part of any study, the Bear Creek project sites were monitored for success (Isenhart, et al., 1997). The monitoring studies indicated that the 21-foot-wide switchgrass component of the model reduced sediment load to the stream by 75%. Nitrate-nitrogen concentrations moving in groundwater below the buffer were markedly lower than those moving below the adjacent, cropped field. Nitrate levels below the buffer never exceeded 2 mg/l while levels below adjacent fields consistently exceeded 12 mg/l (Schultz et al., 1995). In contrast, groundwater nitrate concentrations in a field cultivated to the stream's edge showed no reduction nearer the stream. Wildlife use of the restored area was also markedly improved. While only four bird species per day were observed in channelized reaches, 18 species per day were recorded in 4-year-old buffer sections. Additionally, constructed wetland outflow concentrations of nitrate-nitrogen were significantly lower than inflow concentrations during most sampling periods.

The Iowa management system model provides valuable lessons for management within the Upper Mud Pine Creek Watershed. The approach is flexible for site-specific conditions and respectful of private landowners' desires and objectives. Within the Bear Creek Watershed, two relatively small sites were initially built and then used to garner the interest and support of other landowners. Similar management system models hold great promise for application within the study watersheds and include the following major advantages: 1) interception of eroding soil; 2) trapping and transformation of non-point source pollution; 3) stabilization of stream banks; 4) provision of wildlife habitat; 5) production of biomass for on-farm use; 6) production of high-quality hardwood; and 7) enhancement of agro-ecosystem aesthetics (Schultz et al., 1995).

Natural Nitrification Stimulation

Growers Nutritional Solutions of Milan, Ohio has researched and recommends a nutrient management plan that stimulates natural nitrification processes in the soil. The program has been recognized by the Environmental Protection Agency (EPA) as having environmental benefits because less commercial nitrogen needs to be applied (Halbeisen, 2001). The plan has applications and can be used in both agricultural and residential lawn care situations.

The natural nitrification program involves: 1) supplying adequate amounts of calcium to the soil profile and 2) foliar fertilization using high-grade, balanced fertilizer solutions. Research shows that calcium: 1) stimulates nitrogen-fixing soil bacteria like *Azotobacter* which can fix 15-40 lbs of nitrogen/acre/year (Smith et al., 1953); 2) prevents increased solubility of iron and aluminum which negatively affect nitrogen fixation; 3) increases soil porosity and oxygen exchange which is important for conversion of nitrogen to a form that can be used by plants; 4) stimulates earthworm populations, which shred organic matter for bacterial consumption and help to decrease soil compaction. The second part of the program requires applying a small amount of balanced fertilizer on the seed at planting. The crops are then fed through the foliage at certain stages of development. Research shows that foliar-applied fertilizer is used more efficiently than soil-applied nutrition (Joint Committee on Atomic Energy, 1954). Advantages of using the two part program include: 1) lowered use of applied nitrogen; 2) sound economic productivity; 3) higher grain weights; 4) better produce flavor and shelf life; 5) fewer livestock veterinary visits (Halbeisen, 2001).

Integration of Nitrogen and Phosphorus Management

Recent research has suggested the need for integrated nitrogen and phosphorus management to account for spatial variation in nutrient loss risk (Heathwaite et al., 2000). While nitrate-nitrogen loss is a threat to ground water supplies, phosphorus loss threatens rivers, lakes, and oceans with eutrophication (overproduction). Nitrogen as nitrate is highly mobile in leaching water and is primarily lost through subsurface runoff. (Figure 16 shows areas of the state that are vulnerable to nitrate loss via leaching according to modeling work by Purdue University engineering professor Bernie Engel.) On the other hand, phosphorus is predominantly lost via surface runoff. Because the two nutrients are transported by such different mechanisms, different management tools should be employed depending on which nutrient is of the highest risk of being lost. For example, it does not make sense to prioritize management of phosphorus in an area of the watershed that rarely contributes surface runoff and that does not receive high amounts of the nutrient. Different sections of even a single tract of land may need to be managed differently based on risk of nutrient loss.

In many cases, "across-the board" management of only one nutrient may in fact heighten the risk of pollution by the other. For example, when manure fertilization regimes are based on soil nitrogen content alone to manage nitrate leaching, phosphorus is often over-applied. The amount of phosphorus applied relative to nitrogen (N:P = 2:1 to 6:1) is often greater than that which can be taken up by crops (N:P = 7:1 to 11:1) (Eck and Stewart, 1995). In contrast, use of artificial drainage to reduce phosphorus loss by reducing surface runoff may enhance nitrate leaching through the ground (Turtola and Paajanen, 1995).

Individual tracts of land can be assessed for nutrient loss risk by applying nitrogen and phosphorus indexing systems to assign risk ratings (Heathwaite et al., 2000). The nitrogen index is based on soils texture and permeability, fertilization rate and method, and manure application rate and method. The phosphorus index is based on erosion potential, amount of runoff that leaves the site, distance from the site to the nearest waterway, soil test phosphorus, fertilization rate and method, and manure application rate and method. By calculating the index value for each nutrient, loss vulnerability for the site can be determined and management tailored accordingly.

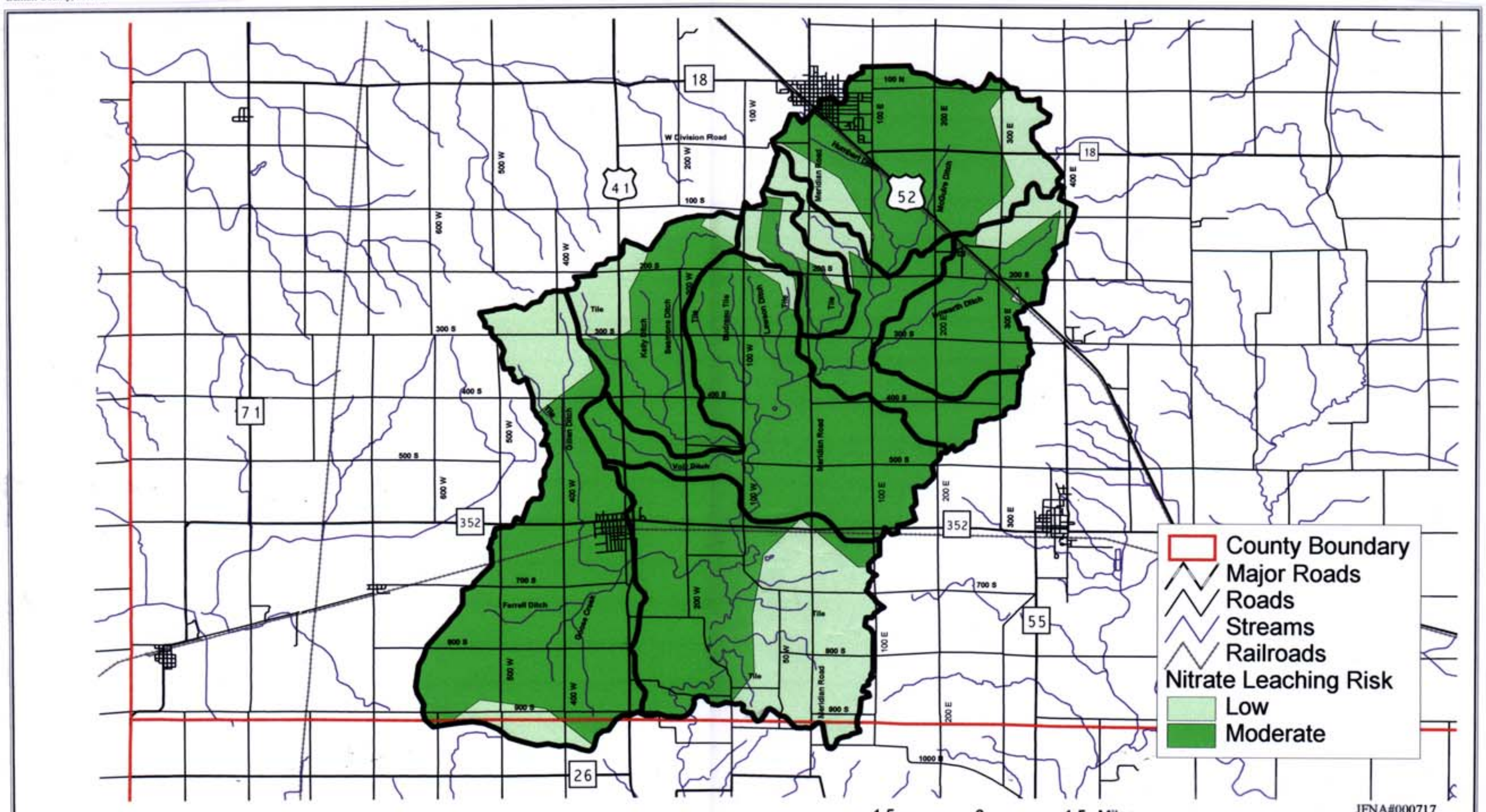

Figure 16
Nitrate Leaching Risk Map
Upper Mud Pine Creek Watershed

In areas that are phosphorus-loss prone, fertilizer and manure applications should be appropriately modified and features that slow surface runoff should be installed (i.e., constructed wetlands and filter strips). In areas where nitrogen loss is a hazard, nitrogen sources and sinks like fertilizer, crop type, and crop rotation should be carefully monitored. Different management priorities may be suited to different areas of a watershed or tract of land.

Water Treatment Residual Application to Reduce Nutrient Loss

Recent research shows that residual chemicals produced during the drinking water purification process may retard nutrient loss from animal wastes applied as fertilizers (Gallimore et al., 1999). Water treatment residuals (WTR) are composed of sediment, aluminum oxide, activated carbon, and polymer. Runoff from plots fertilized with poultry litter including WTRs contained 50% less dissolved phosphorus and 66% less ammonium when compared to runoff from control plots which received poultry litter alone. Land application of the WTR did not increase total dissolved solids or aluminum in surface runoff. The study did note, however, that WTR may damage pasture vegetation and is discouraged (Gallimore et al., 1999).

Nitrification Inhibitors

Nitrification inhibitors are chemicals that can be applied that retard the nitrification process that results in the conversion of ammonium to nitrate. Inhibitor use is especially relevant when there is a gap between applying nitrogen and planting crops. Nitrate reductions of 8 mg/l in the groundwater and nitrate leaching rate reductions of 44.8 kg/ha/yr have been documented in the literature (Yadav, 1997).

Systems of BMPs

Although individual BMPs are commonly and have traditionally been used, recent work shows that BMPs used in concert working as a system will often be more effective at pollution control than individual practices (Osmond et al., 1995). Systems of BMPs function to minimize the pollutant at several points including the source, the transport process, and the water body. For example, the goal of an Iowa Rural Clean Water Program (RCWP) project, was to protect Prairie Rose Lake which was receiving sediment from the surrounding watershed. The BMPs critical area planting and conservation tillage were used to diminish soil loss from agricultural land, while terraces, underground outlets, diversions, grassed waterways, and detention basins were constructed to slow sediment transport to the lake (Osmond et al., 1995).

BMP Summary

Agricultural BMPs are currently used in the Upper Mud Pine Creek Watershed. While most subwatershed basins within study area contain little HEL, the Lower Mud Pine Creek and Goose Creek Subwatersheds do contain small acreages of unprotected highly erodible land. Due to relative lack of current CRP participation, these areas should be targeted in future sign-up efforts and prioritized for BMP installation. Although some cropland within the watersheds is treated using filter strips and grassed waterways, more participation should be sought and encouraged, particularly on highly erodible tracts that border waterways. Currently, some non-protected HEL tracts directly border tributaries to Mud Pine Creek. Conservation tillage is readily used throughout the study watersheds, but farmers should be encouraged to stay with the minimum till practices longer than 2-3 years. The best way to protect against soil loss is to keep the soil covered, minimizing disturbance. As a result of conservation tillage used in combination with other BMPs, 75% of Indiana's cropland is losing soil at or below the tolerable level of T for the 2000 growing season (Evans et al., 2000). In fact, scientific evidence indicates that about 80% of environmental issues that result from cropland can be corrected by integrating BMPs into farm management (CTIC, 1999). Comprehensive land management through development of individual Resource Management Plans is highly recommended.

Stream Chemistry Studies

Introduction

Aside from the current study, few other stream chemistry studies have been conducted in the Upper Mud Pine Creek Watershed. The Indiana Department of Environmental Management (IDEM) assessed four chemical parameters when sampling for macroinvertebrates in 1991, and the United States Geological Survey (USGS) assessed sediment and sediment-related parameters at their gaging station on Mud Pine Creek in 1979 and 1980. Due to the relative lack of historical data, trend analysis was not possible.

IDEM Study

IDEM assessed stream temperature, dissolved oxygen, conductivity, and pH as part of a macroinvertebrate sampling event in Mud Pine Creek just south of the study watershed on September 25, 1991 (Table 25; Figure 17). All parameters were within ranges sufficient for aquatic life. (Please see the Water Chemistry Methods Section of this report for a more detailed description of water quality parameters.)

TABLE 25. Mud Pine Creek stream chemistry data collected in Warren County just south of the Upper Mud Pine Creek Watershed (CR 850N) by IDEM on September 25, 1991.

Parameter	Result
Temperature (°C)	15.36
Dissolved Oxygen (mg/l)	9.92
Conductivity (μohms/cm^2)	699
pH	7.92

USGS Study

The USGS measured sediment and discharge on numerous dates in 1979 and 1980 at their gaging station near Boswell in the Upper Mud Pine Creek Watershed (Figure 17). During each sampling event, particles smaller than 0.062mm consistently composed more than 97% of the sample (Table 26). Temperatures followed a normal seasonal pattern and sediment loading ranged from close to 0 up to 5,250 tons/day (Table 27). Sediment concentration in samples measured as total suspended solids (TSS) was directly correlated with discharge rate, and the relationship was statistically significant (Figure 18; $p=0.002$; $r^2=0.52$). A direct relationship (i.e. higher rates of discharge correlate with higher sediment content in stream water) suggests that runoff events are probably coupled with soil erosion from the land and/or stream banks. It is important to note that although a linear relationship described the data fairly well ($r^2=0.52$), non-linear regression was not performed, and a non-linear equation may fit the data better.

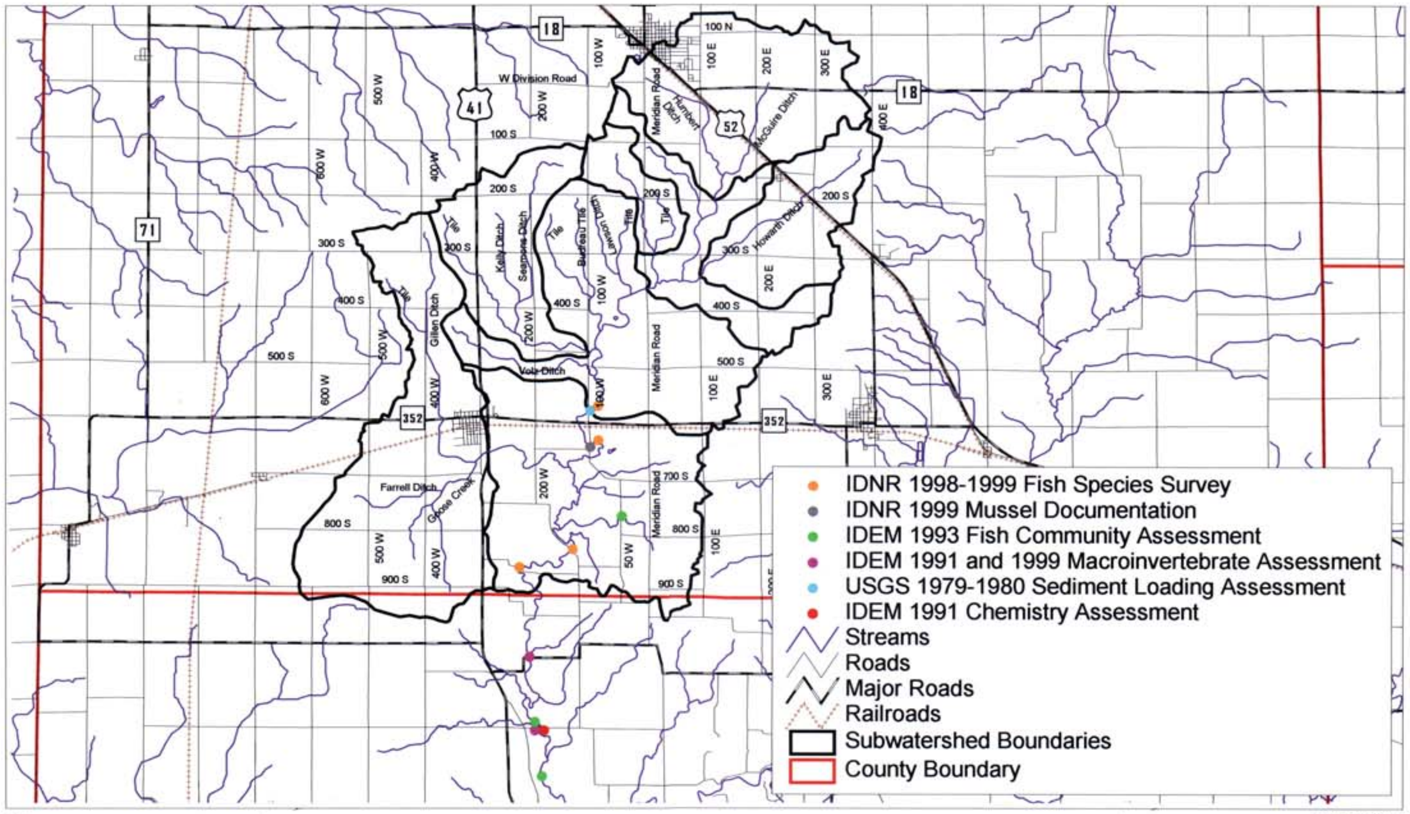

Figure 17
Historical stream chemistry, habitat, and macroinvertebrate, mussel, and fish community survey locations

TABLE 26. Results of USGS fractionation of sediment carried in the Mud Pine Creek stream water on several dates in 1979 and 1980.

Date	Particle Size	% of Sediment in Sample Smaller than Listed Size
3/4/1979	<0.063mm	98
3/4/1979	<0.125mm	98
3/4/1979	<0.25mm	99
3/4/1979	<0.5mm	100
3/19/1979	<0.063mm	98
3/19/1979	<0.125mm	98
3/19/1979	<0.25mm	99
3/19/1979	<0.5mm	99
3/19/1979	<1mm	100
6/20/1979	<0.063mm	98
6/20/1979	<0.125mm	99
6/20/1979	<0.25mm	99
6/20/1979	<0.5mm	100
7/16/1979	<0.063mm	98
7/16/1979	<0.125mm	99
7/16/1979	<0.25mm	100
4/8/1980	<0.063mm	97
4/8/1980	<0.125mm	99
4/8/1980	<0.25mm	99
4/8/1980	<0.5mm	100

TABLE 27. Mud Pine Creek temperature and sediment loading data collected by the USGS in the Upper Mud Pine Creek Watershed in 1979-1980.

Date	Temp. (^oC)	Flow (cfs)	TSS (mg/l)	TSS Load (tons/day)
3/4/1979	0	1990	977	5250
3/19/1979	8	131	524	185
4/23/1979	14	32.2	46	4.01
6/11/1979	22	10.6	22	0.63
6/20/1979	20.5	109	797	235
7/16/1979	26	27.8	333	25
8/28/1979	NS	14	76	2.9
10/9/1979	NS	1.2	7	0.02
11/27/1979	NS	76	32	6.6
1/8/1980	NS	29	29	2.3
2/11/1980	NS	6.2	0.1	0
4/8/1980	9	91	137	34
7/30/1980	28	1.8	78	0.38
9/10/1980	26	0.68	13	0.02
11/13/1980	7	0.6	8	0.01

NS=Not sampled.

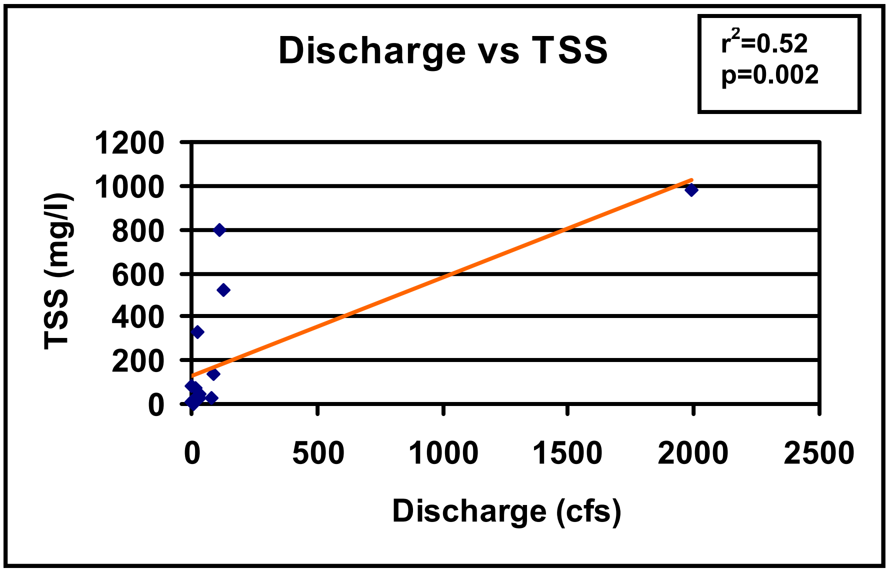

FIGURE 18. Statistically significant relationship between total suspended solids (TSS) and discharge as sampled by the USGS in 1970 and 1980.

Macroinvertebrate Community and Habitat Studies

IDEM Studies

IDEM conducted the only other previous macroinvertebrate and habitat assessment in the general area. On September 25, 1991 the IDEM Biological Studies Section recorded habitat characteristics and sampled macroinvertebrates in Mud Pine Creek just south of the study watershed (Figure 17). An IDEM sampling crew returned to the same general area in 1999 and collected macroinvertebrates but did not sample habitat. Although the IDEM sampling sites do not correspond with any of the sites sampled during this study, the IDEM results will be discussed in comparison with samples collected during this study in the Stream Sampling and Assessment Section. Results of the habitat analysis and macroinvertebrate counts are given in Tables 28 and 29.

TABLE 28. Qualitative Habitat Evaluation Index (QHEI) scores for the site on Mud Pine Creek as assessed by the IDEM Biological Studies Section on September 25, 1991.

Site	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	Total
Maximum Possible Score	20	20	20	10	12	8	10	100
Mud Pine Creek at CR 850N	14	10	12	4	7	0	8	55

TABLE 29. mIBI (macroinvertebrate index of biotic integrity) scores for Mud Pine Creek sampled by the IDEM Biological Studies Section on September 25, 1991 at CR 850N and on July 28, 1999 at SR 26.

	Value	Metric Score
Mud Pine Creek at CR 850N		
HBI	4.27	6
No. Taxa (families)	396	8
No. Individuals	20	8
% Dominant Taxa	50.8	2
EPT Index	315	8
EPT Count	9	8
EPT Count/Total Count	54	4
EPT Abun./Chir. Abun	5.83	6
Chironomid Count	0.80	8
No. Individuals/Square	396	6
mIBI Score		**6.4**
Mud Pine Creek at SR 26		
HBI	4.46	6
No. Taxa (families)	14	4
No. Individuals	189	4
% Dominant Taxa	21.7	8
EPT Index	7	6
EPT Count	105	6
EPT Count/Total Count	0.56	6
EPT Abun./Chir. Abun	2.92	4
Chironomid Count	36	4
No. Individuals/Square	189	6
mIBI Score		**5.4**

In general, habitat quality was found to be of poor quality for aquatic life, scoring 55 of a possible 100 points. However, the mIBI score of 6.4 out of a possible 8 points indicates unimpaired water quality based on the macroinvertebrate community attributes scored by the index. The mIBI score estimated in 1999 places water quality in Mud Pine Creek in the slightly impaired category. Both the QHEI and the mIBI will be discussed in more detail in the Stream Sampling and Assessment Section.

Mussel Survey

IDNR Survey

The IDNR Division of Fish and Wildlife Non-Game Section documented mussel shells while conducting surveys for the state endangered bluebreast darter (*Etheostoma camurum*) in the Mud Pine Creek drainage in Benton County (Figure 17). Table 30 lists the species seen at the site on June 23, 1999. Note that some of the shells were weathered and dead.

TABLE 30. Mussel shells documented by the IDNR during a fish collection on June 23, 1999.

Scientific Name	Common Name	Best Condition Seen
Anodontoides ferrussacianus	Cylindrical papershell	Fresh dead shells
Fusconaia flava	Wabash pigtoe	2 live
Lampsilis siliquoidea	Fatmucket	Weathered dead shells
Lasmigona complanata	White heelsplitter	Weathered dead shells
Villosa lienosa	Little spectaclecase	Weathered dead shells

Fish Community Studies

Introduction

IDEM and the Indiana Department of Natural Resources (IDNR) have conducted several fisheries and fish community surveys in the Upper Mud Pine Creek Watershed in the past 10 years. Mud Pine Creek was surveyed in 1993 by IDEM Biological Studies Section and in 1998-1999 by the IDNR Division of Fish and Wildlife Non-Game Section. IDEM surveys are intended to assess water quality by evaluating the quality of the organisms living in the water. IDNR non-game surveys are generally targeted documentation of state threatened, rare, endangered, or otherwise significant species and their habitat.

IDEM Studies

As part of their assessment of water quality in Indiana, IDEM uses fish communities as an indicator of stream biological integrity or health. Biological integrity has been defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to the best natural habitats within a region" (Karr and Dudley, 1981), and biological communities reflect watershed conditions since they are sensitive to changes in a wide array of environmental factors (Karr, 1981). To provide a method of determining biological integrity, Karr (1981) developed the Index of Biotic Integrity (IBI). Simon (1997) further modified the IBI for evaluation of warmwater stream communities located in the Northern Indiana Till Plain Ecoregion of Indiana. The IBI is composed of 12 metrics which are each individually scored based on types and numbers of fish collected in each sample. A score of 12-22 would indicate very poor stream quality while the maximum score of 60 would indicate excellent conditions.

IDEM conducted three fish community surveys within the Mud Pine Creek Watershed (Figure 17) and calculated IBI scores for each site in 1993 (Table 31). IBI values were directly correlated with distance downstream, meaning that headwater areas were of poorer water quality and supported more pollution-tolerant individuals than reaches further downstream. Only one of the three reaches sampled was within the Upper Mud Pine Creek Watershed boundary, and this reach received a "fair" integrity class score of 40. Reaches further downstream scored "good" (50) and "good-excellent" (54). At the CR 50 W site in the Upper Mud Pine Creek Watershed, the IBI score suffered due to low numbers of sensitive species and high numbers of omnivorous individuals and pioneer species (Table 32). These metric scores can indicate loss of habitat, anthropogenic stress, a disturbed or unbalanced food chain, or other wise unstable environment.

TABLE 31. IBI and integrity class for sites in the Upper Mud Pine Creek Watershed area as sampled by the IDEM Biological Studies Section in the summer of 1993. Sites are listed from the location furthest upstream (CR 50 W) to that furthest downstream (Old US 41).

Site (Location)	Date	IBI	Integrity Class
Tributary to Mud Pine Creek at CR 50 W	8/11/93	40	Fair
Mud Pine Creek at CR 850 N	8/11/93	50	Good
Mud Pine Creek at Old US 41	8/11/93	54	Good-Excellent

TABLE 32. Common names of fish species collected by the IDEM Biological Studies Section at three sites in the Mud Pine Creek drainage during August of 1993. Sites are listed from the location furthest upstream (CR 50 W) to that furthest downstream (Old US 41). The CR 50 W site is on an unnamed tributary to Mud Pine Creek.

Common Name	CR 50 W	CR 850 N	Old US 41
Creek chub	X	X	X
Sand shiner		X	X
Mimic shiner		X	
Suckermouth minnow		X	X
Central stoneroller	X	X	X
Bluntnose minnow	X	X	X
Steelcolor shiner		X	
Shorthead redhorse		X	
Black redhorse		X	X
Golden redhorse		X	X
Greater redhorse		X	
Northern hogsucker		X	X
Stonecat		X	X
Longear sunfish		X	X
Greenside darter		X	X
Rainbow darter		X	X
Fantail darter		X	X
River chub			X
Rosyface shiner			X
Silverjaw minnow			X
Bigeye chub			X
Spotfin shiner			X
Striped shiner	X		X
Redfin shiner			X
White sucker	X		X
Quillback			X
Rock bass			X
Green sunfish	X		X
Bluegill			X
Largemouth bass			X
Spotted bass			X
Bluntnose darter			X
Johnny darter	X		X
Bluebreast darter			X
Orangethroat darter	X		
Blacknose dace	X		
Creek chubsucker	X		

IDNR Studies

The IDNR Division of Fish and Wildlife Non-Game Section surveyed four sites located in the southernmost reach of Mud Pine Creek in Benton County in 1998 and 1999 (Figure 17). All sites surveyed fall within the Upper Mud Pine Creek Watershed. The survey was intended to document the presence of the state endangered bluebreast darter (*Etheostoma camurum*) in the drainage. The bluebreast darter was found up to the CR 100 W bridge; however, sampling just north of Chase upstream of SR 352 failed to take any bluebreast darters. Table 33 documents the fish captured during the IDNR special species survey. The IDNR notes that the lists “do not adequately represent the entire fish community at each location, but are simply lists of the species encountered while searching for the bluebreast darter” (Brant Fisher, personal communication).

TABLE 33. Fish captured during the 1998-1999 IDNR Non-Game Survey of Mud Pine Creek. Sites are listed from the location furthest upstream (SR 352) to that furthest downstream (CR 850 S).

Scientific Name	Common Name	SR 352	CR 100 W	CR 125 W	CR 850 S
Campostoma anomalum	Central stoneroller	X	X	X	X
Cyprinella spiloptera	Spotfin shiner	X	X	X	X
Etheostoma blennioides	Greenside darter	X	X	X	X
Fundulus notatus	Blackstripe topminnow	X	X	X	
Lepomis cyanellus	Green sunfish	X	X	X	
Lepomis megalotis	Longear sunfish	X	X	X	X
Luxilus chrysocephalus	Striped shiner	X	X		X
Lythrurus umbratilis	Redfin shiner	X	X		
Micropterus dolomieu	Smallmouth bass	X			X
Notropis ludibundus	Sand shiner	X	X	X	X
Percina caprodes	Logperch	X			
Phenacobius mirabilis	Suckermouth minnow	X	X		X
Pimephales notatus	Bluntnose minnow	X	X	X	X
Ambloplites rupestris	Rock bass		X		
Ameiurus natalis	Yellow bullhead		X		
Ericymba buccata	Silverjaw minnow		X		
Etheostoma caeruleum	Rainbow darter		X	X	X
Etheostoma camurum	Bluebreast darter		X	X	X
Etheostoma nigrum	Johnny darter		X		
Hybopsis amblops	Bigeye chub		X		
Noturus flavus	Stonecat		X		X
Percina maculata	Blackside darter		X		
Semotilus atromaculatus	Creek chub		X		
Cyprinus carpio	Common carp			X	
Notropis rubellus	Rosey face shiner				X

Exceptional Use Classification

In 1983, the Indiana State Board of Health (ISBH) published a document introducing Indiana's expectional use streams. Although Upper Mud Pine Creek is not mentioned, Lower Mud Pine Creek from the county road between Brisco and Rainsville to its confluence with Big Pine Creek is named as one of eight stream reaches in the state to be designated for "exceptional use". This reach is directly downstream of the Upper Mud Pine Creek Watershed.

Streams classified for exceptional use were defined as 'those which deserve a higher degree of protection than afforded other Indiana streams" (ISBH, 1983). The report goes on to define an exceptional use stream as one having one or more of the following characteristics: 1) preserved in a natural state; 2) contains exceptional habitat or species; 3) contains a rare or endangered species; 4) located in a designated natural area or park; 5) supports an excellent sport fishery; 6) is of exceptional water quality; 7) is of exception aesthetic value; and/or 8) is of exceptional recreational value. The exception value reach of Mud Pine Creek is noted for: 1) colorful sandstone cliffs and outcroppings like Table Rock, a remarkable sandstone landmark formed by erosion; 2) unusually steep gradient; 3) physical characteristics that provide for good aquatic habitat like deep pools, riffles, and high quality substrate; 4) diverse flora along its banks including native relict white pines, red cedar, and bush honeysuckle; 5) "some of the finest fish and wildlife habitat remaining in Indiana" (Bureau of Sport Fishery and Wildlife, US Department of Agriculture); 6) a broad fish species diversity including a smallmouth bass fishery and species considered rare and/or endangered; 7) a broad wildlife species diversity including pheasant, fox, quail, mink, and badgers; and 8) relatively little evidence of man's influence on the landscape; 9) outstanding recreational opportunities including canoeing, hiking, and fishing; and 10) excellent water quality as biologists from the ISBH found eight species of mayflies from five genera living in the water (ISBH, 1983).

Natural Communities and Endangered, Threatened, and Rare Species

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, or rare species, high quality natural communities, and natural areas in Indiana. The database was developed to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the Indiana Department of Natural Resources (IDNR). Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of a species or natural area does not guarantee that the listed species is present or that the listed area is in pristine condition. To assist users, the database includes the date that the species or special habitat was last observed and reported in a specific location.

Results from the database search for the Mud Creek Watershed are presented in Appendix 4. (For additional reference, a listing of endangered, threatened, and rare species documented in Benton County is included in Appendix 5.) According to the database, the Mud Creek Watershed supports two high quality community types, mesic prairie and dry mesic praire. The Franklin's ground squirrel (*Spermophilus franklinii*), short-eared owl (*Asio flammeus*), American badger (*Taxidea taxus*), smooth green snake (*Liochlorophis vernalis*), and bluebreast darter (*Etheostoma camurum*) are all state endangered animal species found within the watershed. Several state endangered plant species also live in the watershed. They include the earleaf foxglove (*Agalinis auriculata*), pitcher's stitchwort (*Arenaria patula*), and forbes saxifrage (*Saxifraga forbesii*). Four state threatened plant species including the downy gentian (*Gentiana puberulenta*), cattail gay-feather (*Liatris pycnostachya*), scarlet hawthorn (*Crataegus pedicellata),* and ledge spike-moss (*Selaginella rupenstris*) have also been documented within the Mud Creek Watershed.

WATERSHED STUDY

The watershed study is composed of two main components: the watershed investigation and the stream sampling and assessment. The watershed investigation entailed both an aerial tour and a windshield survey of the Upper Mud Pine Creek Watershed. The stream sampling and assessment involved: 1) stream water quality sampling at nine sites during baseflow and during stormwater runoff; 2) a Qualitative Habitat Evaluation Index (QHEI) calculation for all nine sites; and 3) a macroinvertebrate Index of Biotic Integrity (mIBI) calculation for each stream sampling site.

Watershed Investigation

Introduction

Targeting areas of concern and selecting sites for future management are the goals of a visual watershed inspection. The study area watersheds were toured by airplane in April of 2001 and a windshield survey was conducted in early January of 2002 after most crops were removed. The results of and observations made during these two surveys are presented below. Figure 19 offers a summary of observations made during the both the aerial tour and the windshield survey.

Aerial Tour

The aerial tour consisted of flying over the watershed at fairly low altitudes in order to photograph high priority and environmentally sensitive areas. Areas of concern with corresponding aerial photos are discussed by subwatershed, and their locations are mapped on Figure 19. Photos of unique problems are included in the discussion of each subwatershed.

Humbert Ditch Subwatershed. Four sites where management practice implementation may be possible were noted during the aerial tour of Humbert Ditch (Table 34; Sites A1-A5; Figure 19). revegetation and filter strip or grassed waterway construction could help slow erosion at all five sites. Site A4 (Figure 20) also offers potential for a wetland restoration project which would expand water-holding capacity in the watershed and help slow erosion processes downstream. Restored wetlands increase water holding/storage capacity in the watershed, thereby reducing runoff volumes during storm events. Large, uncontrolled runoff events can cause soil and bank destabilization and erosion. Wetlands also offer mechanical and biological filtration of water that effectively removes sediment, pathogens, nutrients, and other chemicals from runoff.

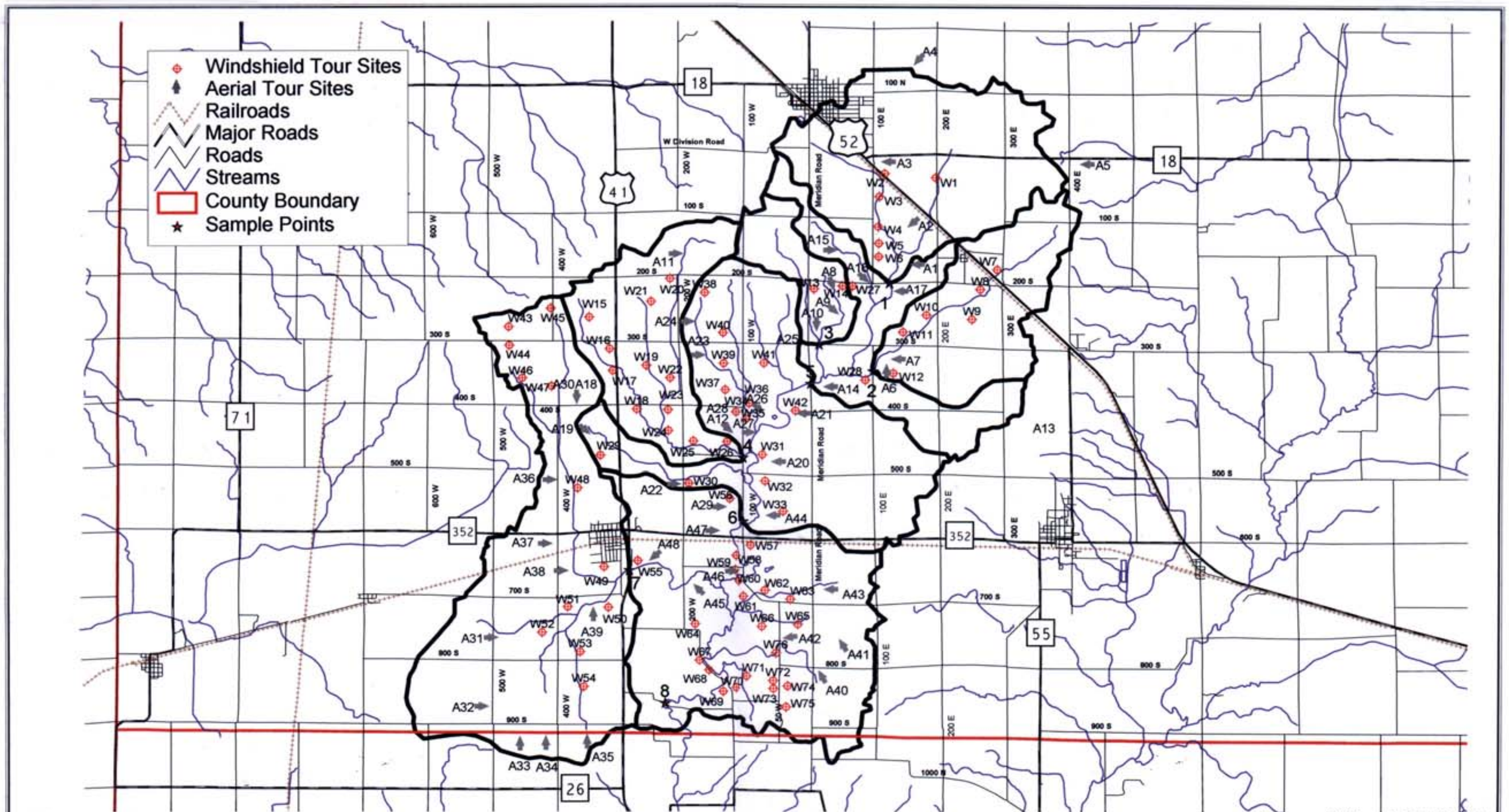

Figure 19
Aerial Tour and Windshield Survey Site Location Map
Upper Mud Pine Creek Watershed

TABLE 34. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Humbert Ditch Subwatershed. Causes of impairment and practices that could be used to treat them are also listed. Site A1 involves both Humbert and McGuire Ditches. Sites A2-A4 are located along Humbert Ditch or in its drainage. Site A5 is in the drainage of McGuire Ditch.

Site	Cause	Management Practice
A1	Several areas where soil was bare were noted	Allow for natural riparian vegetation growth; revegetate bare soil areas
A2	Land is farmed to stream's edge	Filter strips
A3	Land is farmed to stream's edge	Filter strips
A4	Rill and gully erosion was evident; land is farmed to stream's edge	Grassed waterway; filter strips; wetland restoration is possible
A5	Rill and gully erosion was evident	Grassed waterway

FIGURE 20. Site A4 showing a potential wetland restoration site in the Humbert Ditch Subwatershed.

Howarth Ditch Subwatershed. Aerial photo documentation of the Howarth Ditch Subwatershed only revealed two locations where land management actions could improve water quality (Table 35; Sites A6 and A7; Figures 19 and 21); however, photos of the upstream reach of Howarth Ditch were not detailed enough to discern individual problems. For this reason, additional time was spent in the Howarth Ditch area during the windshield survey. The area will be discussed in more detail in the Windshield Survey Section.

TABLE 35. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Howarth Ditch Subwatershed. Causes of impairment and practices that could be used to treat them are also listed. Both sites are located on Howarth Ditch.

Site	Cause	Management Practice
A6	Land is farmed to stream's edge	Filter strips
A7	Land is farmed to stream's edge	Filter strips

FIGURE 21. Site A6 showing filter strip needs in the Howarth Ditch Subwatershed.

Wattles Ditch Subwatershed. Three more locations where filter strip application would be appropriate were documented in the Wattles Ditch area (Table 36; Site A8-A10; Figure 19). Because these sites overlap with areas that have been documented as having major erosion problems, filter strips could potentially have a disproportionate, beneficial effect on water quality.

TABLE 36. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Wattles Ditch Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Site	Cause	Management Practice
A8	Ground above a buried tile is farmed and is eroding.	Grassed waterway maintenance
A9	Land is farmed to stream's edge	Filter strips
A10	Land is farmed to stream's edge	Filter strips

Seamons Ditch Subwatershed. As was the case with photos of the Howarth Ditch Subwatershed, aerial photos of the Seamons Ditch Subwatershed also resulted in identification of only two areas where BMPs may be appropriate (Table 37; Sites A11 and A12; Figure 19). The areas that were not photographed during the aerial tour received greater attention during the windshield survey. The land at the headwaters of Seamons Ditch appeared to have been overgrazed, and livestock should be excluded from the stream and its riparian area to preserve banks and prevent water contamination. The length of Seamon's Ditch at Site A12 would benefit from filter strips or other agriculture set-back zone.

TABLE 37. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Seamons Ditch Subwatershed. Causes of impairment and practices that could be used to treat them are also listed. Both sites are located on Seamons Ditch.

Site	Cause	Management Practice
A11	Banks are eroding; the site appears to have been heavily grazed	Allow for natural riparian vegetation growth; fence livestock from stream area
A12	Land is farmed to the stream's edge	Filter strips

Upper Mud Pine Creek Subwatershed. Producers were farming land up to or very near the ditch's banks at all four of the five documented sites in the Upper Mud Pine Creek Subwatershed (Sites A14-17; Table 38; Figure 19). Water quality in Mud Pine Creek could be improved by filter strip installation and riparian protection in these areas. Additionally, an opportunity for wetland restoration exists on the eastern edge of the drainage (Site A13; Figure 22).

TABLE 38. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Upper Mud Pine Creek Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Site	Cause	Management Practice
A13	NA	Wetland restoration is possible
A14	Land is farmed to stream's edge	Filter strips
A15	Land is farmed to stream's edge	Filter strips
A16	Land is farmed to stream's edge	Filter strips
A17	Land is farmed to stream's edge	Filter strips

NA=Not applicable.

FIGURE 22. Site A13 showing potential wetland restoration sites in the Upper Mud Pine Creek Subwatershed.

Volz Ditch Subwatershed. Table 39 contains data relevant to 12 sites in the Volz Ditch Subwatershed where land treatment actions could improve water quality (Site A18-29; Figure 19). Constant stream bank disturbance either due to production, livestock, or other activities impacts the riparian area at the majority of the 12 sites. Fairly severe bank erosion was notable from the air at Site A22 (Figure 23), and riparian zone disturbance was evident at Site A26 (Figure 24) where a dirt access road is in use. Site A18 near the headwaters of Volz Ditch appears to offer possibilities for wetland restoration.

TABLE 39. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Volz Ditch Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Site	Cause	Management Practice
A18	NA	Wetland restoration is possible
A19	Land is farmed to the stream's edge	Filter strips are needed east of SR41
A20	Land is farmed to the stream's edge	Filter strips
A21	Land is farmed to the stream's edge	Filter strips
A22	Banks are eroding; land is farmed to the stream's edge	Bank stabilization; filter strips
A23	Land is farmed to the stream's edge	Filter strips
A24	Ground above a buried tile is farmed and is eroding.	Grassed waterway maintenance
A25	Land appears to have been heavily grazed; land is farmed to the stream's edge	Livestock fencing; allow for natural riparian vegetation growth; filter strips
A26	A dirt road is utilized near the stream's edge; land is farmed to the stream's edge	Minimize disturbance close to the stream; filter strips
A27	Land appears to have been heavily grazed	Livestock fencing; allow for natural riparian vegetation growth
A28	Land appears to have been heavily grazed; land is farmed to the stream's edge	Livestock fencing; allow for natural riparian vegetation growth; filter strips
A29	Land appears to have been heavily grazed	Livestock fencing; allow for natural riparian vegetation growth

FIGURE 23. Site A22 showing bank erosion along Volz Ditch.

FIGURE 24. Site A26 showing a dirt access road in the riparian area adjacent to Mud Pine Creek.

Goose Creek Subwatershed. Ten potential management practice locations were documented during the aerial tour of the Goose Creek Subwatershed (Table 40; Sites A18-29; Figure 19). filter strip application could be encouraged at Sites A31, 35, 36, and 39. Grassed waterways could also be recommended to protect against further rill and gully erosion at Site A32 and 35. As with any project, continued maintenance is required to ensure continued functionality and benefit. Grassed waterway maintenance is needed at Site A33 and A34 to widen existing waterways that have been narrowed over time. Additionally, two opportunities for wetland restoration exist at Sites A30 and 37.

TABLE 40. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Goose Creek Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Site	Cause	Management Practice
A30	NA	Wetland restoration is possible
A31	Land is farmed to stream's edge	Filter strips
A32	Rill and gully erosion was evident	Grassed waterway and/or conservation tillage
A33	Grassed waterway has been narrowed at its upper end	Grassed waterway maintenance
A34	Grassed waterway has been narrowed	Grassed waterway maintenance
A35	Rill and gully erosion was evident; land is farmed to the stream's edge	Grassed waterway and/or conservation tillage; filter strips
A36	Land is farmed to stream's edge	Filter strips
A37	NA	Wetland restoration is possible
A38	Land is farmed to stream's edge	Widen out existing filter strip areas
A39	Land is farmed to stream's edge	Filter strips

Lower Mud Pine Creek Subwatershed. Several locations within the Lower Mud Pine Creek Subwatershed are being farmed up to the stream's edge and need filter strip set-back areas (Table 41; Sites A40, 42, 43, and 45-48; Figure 19). Additional areas where livestock fencing and wetland restoration are applicable are also listed in Table 41.

TABLE 41. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Lower Mud Pine Creek Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Site	Cause	Management Practice
A40	Land is farmed to stream's edge	Filter strips
A41	NA	Wetland restoration is possible
A42	Land is farmed to stream's edge	Filter strips
A43	Land is farmed to stream's edge	Filter strips
A44	Land appears to have been heavily grazed	Livestock fencing
A45	Land is farmed to stream's edge	Filter strips
A46	Land appears to have been heavily grazed; land is farmed to the stream's edge	Livestock fencing; allow for natural riparian vegetation growth; filter strips
A47	Rill and gully erosion is evident	Grassed waterway maintenance and/or conservation tillage
A48	Land is farmed to stream's edge	Filter strips

Windshield Tour

Introduction

The windshield survey was conducted on January 8, 2002 and entailed driving the watersheds and assessing the streams where they crossed or were located adjacent to roads. Jason Kimbrough of the Benton County SWCD, Julie McLemore of the USDA-NRCS, Tom Glotzbach a Benton County SWCD Board supervisor, Neil Deckard of the Newton County SWCD, and Deiter Markland and Jennifer Bratthauer of the IDNR accompanied J.F. New and Associates during the windshield tour. Particular areas of concern were examined more closely by stopping and walking areas within public right-of-way. Some facilities like the Fowler Municipal Wastewater Treatment Plant (WWTP) were toured as well.

Observations made during the windshield tour fall into two different classes: those relating to sites having potential for best management practice implementation (like fields bordering streams and needing filter strips) and those relating to sites or operations which may contribute point or non-point source pollution to the streams (like the Boswell WWTP). These two classes are discussed below and their locations appear on Figures 19 and 25.

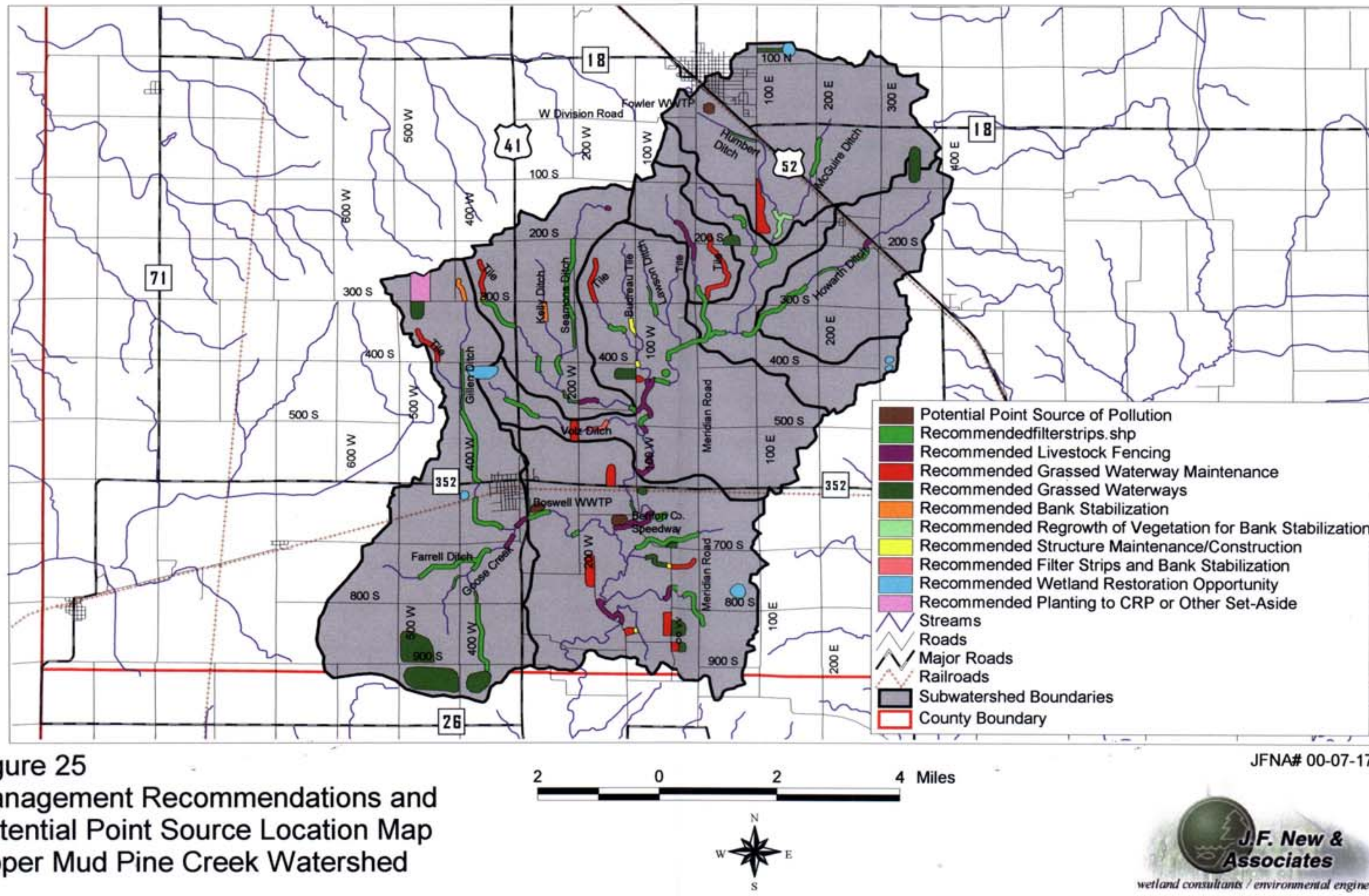

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Figure 25
Management Recommendations and
Potential Point Source Location Map
Upper Mud Pine Creek Watershed

J.F. New & Associates
wetland consultants / environmental engineers

Sites for Potential Management Practice Implementation

Most observations made during the windshield tour relate to needs for better management practice implementation in the study areas. Table 42 lists all sites where BMPs could benefit water quality by number and by subwatershed and lists any corresponding photos that were taken of each site while on the tour. Site locations are displayed in Figure 19, and photos appear in Figures 26-31.

TABLE 42. List of sites and corresponding BMPs compiled during the windshield survey portion of the Upper Mud Pine Creek Watershed.

Subwatershed	Site	Recommended BMP
Humbert Ditch	W1	Filter strips
Humbert Ditch	W2	Channel maintenance because flow is somewhat restricted through this area
Humbert Ditch	W3	Grassed waterway maintenance
Humbert Ditch	W4	Grassed waterway construction
Humbert Ditch	W5	Grassed waterway maintenance
Humbert Ditch	W6	Grassed waterway maintenance
Howarth Ditch	W7	Fence livestock from stream (see photo in Figure 26)
Howarth Ditch	W8	Filter strips (see photo in Figure 27)
Howarth Ditch	W9	Enlarge filter strip width
Howarth Ditch	W10	Filter strips
Howarth Ditch	W11	Filter strips
Howarth Ditch	W12	Filter strips
Wattles Ditch	W13	Fence livestock from stream
Wattles Ditch	W14	Grassed waterway maintenance
Seamons Ditch	W15	Grassed waterway maintenance and grade stabilization structures
Seamons Ditch	W16	Filter strips
Seamons Ditch	W17	Enlarge filter strip width
Seamons Ditch	W18	Enlarge filter strip width
Seamons Ditch	W19	Bank stabilization (see photo in Figure 28)
Seamons Ditch	W20	Filter strips
Seamons Ditch	W21	Filter strips
Seamons Ditch	W22	Filter strips
Seamons Ditch	W23	Enlarge filter width
Seamons Ditch	W24	Fence livestock from stream
Seamons Ditch	W25	Filter strips
Seamons Ditch	W26	Filter strips
Upper Mud Pine Creek	W27	Grassed waterway construction
Upper Mud Pine Creek	W28	Enlarge filter strip width; bank stabilization (see photo in Figure 29)
Volz Ditch	W29	Filter strips
Volz Ditch	W30	Grassed waterway maintenance
Volz Ditch	W31	Filter strips
Volz Ditch	W32	Fence livestock from stream

Volz Ditch	W33	Fence livestock from stream (see photo in Figure 30)
Volz Ditch	W34	Grassed waterway construction
Volz Ditch	W35	Grassed waterway maintenance
Volz Ditch	W36	Grade stabilization structures
Volz Ditch	W37	Revegetation exposed areas on newly constructed grassed waterway
Volz Ditch	W38	Grassed waterway maintenance
Volz Ditch	W39	Rebuild structure
Volz Ditch	W40	Filter strips
Volz Ditch	W41	Filter strip and set barnyard back from edge of stream
Volz Ditch	W42	Filter strips and revegetation of areas left exposed by ditch maintenance
Goose Creek	W43	Enroll steep hill in CRP; at minimum this ground should be conservation-tilled
Goose Creek	W44	Grassed waterway construction
Goose Creek	W45	Bank stabilization
Goose Creek	W46	Grassed waterway maintenance
Goose Creek	W47	Grassed waterway construction
Goose Creek	W48	Filter strips
Goose Creek	W49	Fence livestock from streams
Goose Creek	W50	Fence livestock from streams
Goose Creek	W51	Filter strips
Goose Creek	W52	Filter strips
Goose Creek	W53	Enlarge filter strip width
Goose Creek	W54	Filter strips
Lower Mud Pine Creek	W55	Filter strips
Lower Mud Pine Creek	W56	N/A IDNR gamebird habitat
Lower Mud Pine Creek	W57	Grassed waterway construction
Lower Mud Pine Creek	W58	Enlarge filter strip width
Lower Mud Pine Creek	W59	N/A Benton County Speedway
Lower Mud Pine Creek	W60	Fence livestock from streams
Lower Mud Pine Creek	W61	Enlarge filter strip width
Lower Mud Pine Creek	W62	Filter strips
Lower Mud Pine Creek	W63	Grassed waterway construction
Lower Mud Pine Creek	W64	Grassed waterway maintenance
Lower Mud Pine Creek	W65	Grassed waterway maintenance
Lower Mud Pine Creek	W66	Grade stabilization structures; grassed waterway construction
Lower Mud Pine Creek	W67	Gully stabilization; grade stabilization structures
Lower Mud Pine Creek	W68	Fence livestock from streams; bank stabilization (see photo in Figure 31)
Lower Mud Pine Creek	W69	Bank stabilization
Lower Mud Pine Creek	W70	Grassed waterway and structure maintenance
Lower Mud Pine Creek	W71	Grassed waterway construction
Lower Mud Pine Creek	W72	Grassed waterway maintenance
Lower Mud Pine Creek	W73	Grassed waterway maintenance

Lower Mud Pine Creek	W74	Grassed waterway construction
Lower Mud Pine Creek	W75	Grassed waterway construction and maintenance
Lower Mud Pine Creek	W76	Fence livestock from stream

FIGURE 26. Site W7 taken during the windshield survey showing a need for livestock fencing in the Howarth Ditch Subwatershed.

FIGURE 27. Site W8 taken during the windshield survey showing unstable banks and the need for filter strips in the Howarth Ditch Subwatershed.

FIGURE 28. Site W19 taken during the windshield survey showing a need for bank stabilization in the Seamons Ditch Subwatershed.

FIGURE 29. Site W28 taken during the windshield survey showing a need for filter strips and bank stabilization in the Upper Mud Pine Creek Subwatershed.

FIGURE 30. Site W33 taken during the windshield survey showing a need for livestock fencing in the Volz Ditch Subwatershed.

FIGURE 31. Site W68 taken during the windshield survey showing a need for livestock fencing and bank stabilization in the Lower Mud Pine Creek Subwatershed.

Potential Contributors of Point or Non-Point Source Pollution

Some observations made during the windshield survey revealed operations that may contribute to water pollution in more direct ways. Because no data was collected during this study to test effluent or runoff from any of the following areas, facilities, or operations, it was not possible to determine if or to what extent their activities may contribute to water pollution. The current study documented their existence and location and recognized their potential to contribute to either point or non-point source pollution.

Humbert Ditch Subwatershed. The town of Fowler discharges both untreated stormwater and treated municipal wastewater into Humbert Ditch. The Fowler Municipal Waste Water Treatment Plant (WWTP) treats sewage from the incorporated town (Alan Leuck, plant superintendent, personal communication). The plant is permitted as a point source by the state of Indiana. As in most small towns in the Midwest, little infrastructure exists for stormwater treatment. The town of Fowler currently maintains two storm water detention ponds, and during rain events, catch basins and the detention ponds collect water and conduct it to the Barnard and White Tiles which carry stormwater to Humbert Ditch. (Mr. Leuck clarified that the White Tile "does not discharge directly to Humbert Ditch as it used to, but as of 1996, discharges to a grassy swale with a 6:1 slope, over 100 feet wide, with grass setbacks of over 100 feet on each side." The swale is over 1000 feet long and discharges into Humbert Ditch.) Mr. Leuck noted that designs for two additional stormwater detention ponds are in the planning stages at the present time. According to Mr. Leuck, Humbert Ditch receives runoff from about 50% of the town. Mr. Leuck provided chemical data with respect to nutrient concentrations carried in surface runoff from farmland west of Meridian Road upstream of the town and the WWTP. Samples were collected on the west (upstream) side of Adeway (Meridian) Road. These results are documented in Table 43. Total phosphorus concentrations were indicative of pollution, and chemical oxygen demand (COD) levels were elevated suggesting that the runoff was carrying suspended solids (http://www.epa.gov/owow/tmdl/cs7/graph2.html). Mr. Leuck noted that surface erosion from farmed highly erodible land in the headwaters portion of the Humbert Ditch Subwatershed could be contributing to water quality problems (Alan Leuck, personal communication). Additionally, a new 60-family subdivision was being constructed in the Upper Mud Pine Creek Watershed on the southeast side of Fowler. This new development will add to the waste load currently treated by the WWTP and will contribute additional stormwater to Humbert Ditch. According the David Whybrew with Key Engineering Group, erosion and sediment control during development will conform to Indiana codes and measures to control erosion are in place. An additional storm water detention pond is also being planned within the new development. During the windshield tour it was noted that even though Humbert Ditch was "cleaned" only 2 years ago flow is already being slowed due to heavy sediment build-up.

TABLE 43. Chemical concentration data for storm water leaving farm fields upstream of the town of Fowler near Adeway Road as sampled by Alan Leuck on October 24, 2001.

Parameter	Result	Unit	Detection Limit
Nitrate-nitrogen	2.04	mg/l	0.20
Total Kjeldahl nitrogen	4.0	mg/l	1.0
Potassium	9	mg/kg	1
Phosphorus	2.0	mg/l	0.1
COD	73	mg/l	5

Howarth and Volz Ditch Subwatersheds. While no direct point sources were noted within the drainages of Howarth or Volz Ditches, both are scheduled for dredging and maintenance within the next couple years (Jack Steel, Benton County Surveyor, personal communication). Ditch maintenance projects introduce disturbance to natural systems, and the need for the projects indicates that non-point source pollution is contributing sediment and other pollutant loads in large enough quantities to impede drainage. Following the maintenance projects, these ditches and their immediate watersheds should be thoroughly treated with conservation practices to reduce the need for such projects in the future.

Lower Mud Pine Creek Subwatershed. Based on observations made during the windshield tour and Permit Compliance System (PCS) data, the Benton County Speedway and the Boswell Municipal WWTP are currently active in the Lower Mud Pine Creek Subwatershed. The Benton County Speedway is located west of CR100W and just north of SR352 (Figure 25). Car racing events are held at the location near the mainstem of Mud Pine Creek each weekend during the summer months. Although no sampling of any tile drains or runoff from this area was conducted during this study, the racetrack may be a contributor of grease and other petroleum-based materials especially during the summer months. Large numbers of race fans utilizing the septic facilities at the location may also have implications for water quality. The Boswell WWTP located east of the town of Boswell holds a permit to discharge treated municipal wastewater into Goose Creek. About 800 people live in Boswell and contribute wastewater to the plant. There is currently no industry or large businesses in Boswell so the plant treats a relatively small waste load (Jim Whet, Plant Superintendent, personal communication). Chemical content of this discharge will be discussed in more detail in the following section. Although stormwater is not combined with sewer water, the water receives no treatment prior to entering Goose Creek through clay tiles.

Permitted Point Source Discharge Compliance Report Discussion
Two facilities currently hold permits from the state to discharge specified loads of certain pollutants into streams within the study watershed area. Permitted facilities are required to monitor their discharge and submit compliance reports to the state monthly. A facility that discharges amounts of pollutants that exceed their permitted level are in violation and must correct the problem in a timely manner. The Environmental protection Agency (EPA) Envirofacts Warehouse on-line database can be queried to determine if certain facilities consistently meet or violate standard criteria set for discharge effluent. The Envirofacts database website is located at http://www.epa.gov/enviro/html/pcs/pcs_overview.html. Additional information pertaining to NPDES permits, permit compliance, and permit violations may be obtained from IDEM. (Catherine Hess handles municipal discharge permits and may be contacted at (319) 232-8704. Steve Rouch oversees industrial discharge permits; his telephone number is (317) 232-8706. The IDEM file room stores all permit-related records and ccan be reached at (317) 234-0111.)

The Fowler Municipal WWTP treats wastewater from the incorporated town of Fowler and currently holds a permit to discharge treated water into Humbert Ditch. The plant is located at 903 S. Adeway Drive. Discharge water is monitored for dissolved oxygen (DO), pH, TSS, ammonia-nitrogen (NH_3), flow, total residual chlorine, and carbonaceous biological oxygen demand (C-BOD). In general, the Fowler Municipal WWTP rarely violated its permits for chemical parameters from January 1998-September 2001. The parameter of greatest concern was ammonia-nitrogen concentration in treated effluent. Eight percent of the ammonia-nitrogen samples taken during the considered time period violated state standard levels for the protection of aquatic life. Mean levels of other monitored chemical parameters are listed in Table 44.

TABLE 44. Mean concentrations of monitored chemical parameters discharged by the Fowler Municipal WWTP to Humbert Ditch during the monitoring period from January 1998 to September 2001.

Parameter	Value or Range	Units
Average minimum DO	8.6	mg/l
Average pH range	7.1-7.6	pH units
Average maximum TSS	10.8	mg/l
Average maximum NH_3-N	0.90	mg/l
Average maximum total residual chlorine	0.01	mg/l
Average maximum C-BOD	4.3	mg/l

Source: EPA's Envirofacts Warehouse database.

The Boswell Municipal WWTP located on SR41 and Spies Street also currently holds a permit to discharge by-products of municipal waste treatment to Goose Creek. Treatment effluent must meet certain standards for: DO, pH, TSS, NH_3-N, flow, total residual chlorine, and C-BOD. Table 45 contains data similar to that reported for the Fowler Municipal WWTP in Table 44. The Boswell WWTP only exceeded its permitted limits one time from November 1998 to September 2001 for the chlorine parameter; all other samples within the timeframe fell within permitted ranges.

TABLE 45. Mean concentrations of monitored chemical parameters discharged by the Boswell Municipal WWTP to Goose Creek during the monitoring period from November 1998 to September 2001.

Parameter	Value or Range	Units
Average minimum DO	7.2	mg/l
Average pH range	6.9-7.3	pH units
Average maximum TSS	2.0	mg/l
Average maximum NH_3-N	0.37	mg/l
Average maximum total residual chlorine	0.95	mg/l
Average maximum C-BOD	2.0	mg/l

Source: EPA's Envirofacts Warehouse database.

Watershed Investigation Conclusion

The goal of the watershed investigation was to target areas of concern and select sites for future management. Locations identified during both the aerial windshield tours where certain land use management practices are relevant and applicable appear in Figure 25. The aerial tour pointed out areas where filter strip implementation and livestock fencing could benefit water quality especially in the Seamons Ditch, Volz Ditch, and Lower Mud Pine Creek Subwatersheds. Grassed waterway construction or maintenance may be possible in Humbert Ditch, Wattles Ditch, Volz Ditch, Goose Creek, and Lower Mud Pine Creek Subwatersheds according to photos taken during the aerial tour. Areas for wetland restoration in the five of the study subwatersheds were also noted from the air. Additional areas for BMP implementation were documented during the windshield survey including opportunities for: filter strip application, bank stabilization, livestock fencing, revegetation of eroded/disturbed areas, and grassed waterway application. The windshield tour also revealed areas where the IDNR preserves habitat for game birds. Some potential contributors to point and/or non-point source pollution were also documented during the windshield tour. No sampling was conducted to determine pollutant contribution, but potential sources included: a motorcar racetrack, two WWTPs, a new subdivision, and the towns of Fowler and Boswell.

Stream Sampling and Assessment

Introduction

The stream assessment portion of the watershed study consisted of water chemistry sampling during base flow and a storm runoff event, a macroinvertebrate community assessment, and a habitat assessment. Sampling was conducted at eight sites in the Upper Mud Pine Creek Watershed (Figure 32). The stream assessment study provides information that can be analyzed to determine water quality and aquatic habitat impairment. The data can be utilized as a guide for prioritization of management actions and direct those actions toward the most critical areas.

Sampling Locations

Eight stream sites were strategically chosen throughout the Upper Mud Pine Creek Watershed (Figure 32; Table 46). These sites were selected based on accessibility and relative amount of information that could be obtained for each subwatershed. Ideally, the stream assessment protocol would include sampling a reference site for comparative purposes. An ideal reference site would have a relatively undisturbed watershed with little channel alteration and would meet all criteria listed in Table 47. However, because of extensive human activities throughout the watersheds in the study area, a reference site meeting all the criteria in Table 47 could not be located.

TABLE 46. Detailed sampling location information for the Upper Mud Pine Creek Watershed.

Site #	Stream Name	Road Location	Place Sampled	Latitude	Longitude
1	Humbert Ditch	intersection of CR 200 S	north side of CR 200 S	N40°34.652	W87°17.972
2	Howarth Ditch	intersection of CR 100 E	east side of CR 100 E	N40°33.446	W87°18.236
3	Wattles Ditch	intersection of CR 300 S	south side of CR 300 S	N40°33.805	W87°19.192
4	Seamons Ditch	intersection of CR 475 S	upstream of confluence with MPC	N40°32.175	W87°20.333
5	Upper Mud Pine Creek	intersection of Meridian (Adeway) Rd.	east side of Meridian Rd.	N40°33.171	W87°19.202
6	Volz Ditch	intersection of CR 100 W	east side of CR 100 W	N40°31.235	W87°20.305
7	Goose Creek	intersection of US 41	between lanes of highway	N40°30.398	W87°22.324
8	Lower Mud Pine Creek	intersection of CR 850 S	south side of CR 850 S	N40°28.534	W87°21.571

TABLE 47. Minimum criteria for stream reference sites. Source: Plafkin et al., 1999.

Example Criteria for Reference Sites (Must meet all criteria)
• pH >=6; if blackwater stream, then pH <=6 and DOC >8 mg/l • Dissolved Oxygen >= 4 ppm • Nitrate <=16.5 mg/l • Urban land use <=20% of catchment area • Forest land use >=25% of catchment area • Instream habitat rating optimal or suboptimal • Riparian buffer width >=15m • No channelization • No point source discharges

State personnel have suggested two streams that offer potential for use as reference sites: Stoney Creek near Muncie, Indiana and Otter Creek near Terre Haute, Indiana. However, neither of these two streams is located within the same ecoregion as the study area. Because of their location within difference ecoregions, the relevance of comparing Stoney or Otter Creeks with Mud Pine Creek is limited.

Water Chemistry

Water Chemistry Methods

The LARE sampling protocol requires assessing water quality of each stream site once during base flow and once during storm flow. A base flow sampling provides an understanding of the typical conditions in the streams. Following storm events, increased overland water flow results in increased erosion of soil and nutrients from the land. Stream concentrations of nutrients and sediment are higher following storm events. Storm sampling provides a "worst case" scenario picture of watershed pollutant loading. Storm event samples were collected May 18, 2001 following a storm that dumped almost two inches of rain in a 24 hour period. Due to the magnitude of the storm event the soils were likely saturated at the time of sampling. Base flow samples were collected June 26, 2001 following a period of little precipitation. River stage at the Iroquois River equaled the historical median daily stream flow (Figure 33), therefore this sampling date is representative of base flow conditions since smaller streams, such as Mud Pine Creek and its tributaries, responds more rapidly to flows than does the larger Iroquois River. It is important to note that even though these results provide insight into the characteristics of the streams at the particular time of sampling, it is difficult to extrapolate these results to other times of the year and different conditions.

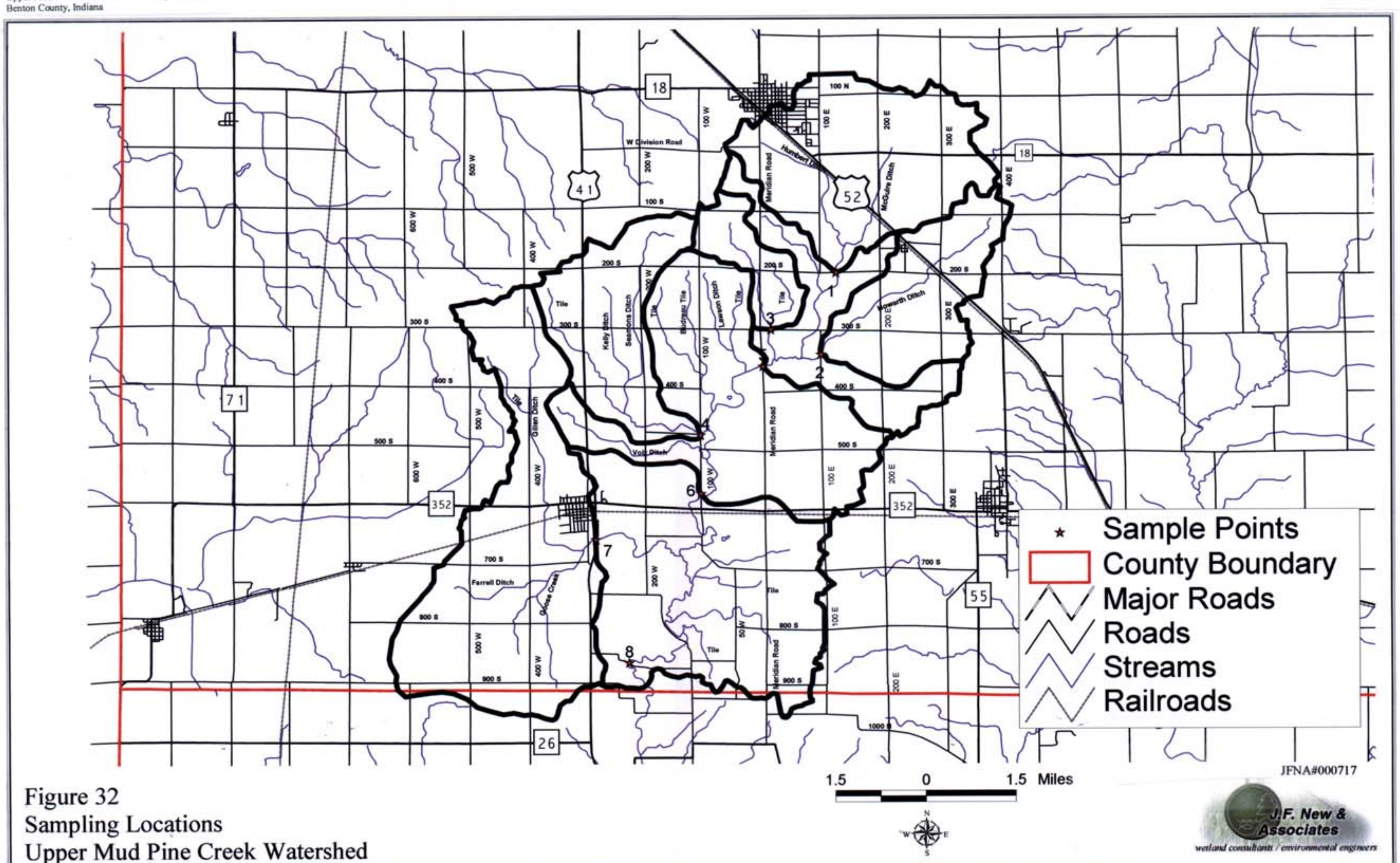

Figure 32
Sampling Locations
Upper Mud Pine Creek Watershed

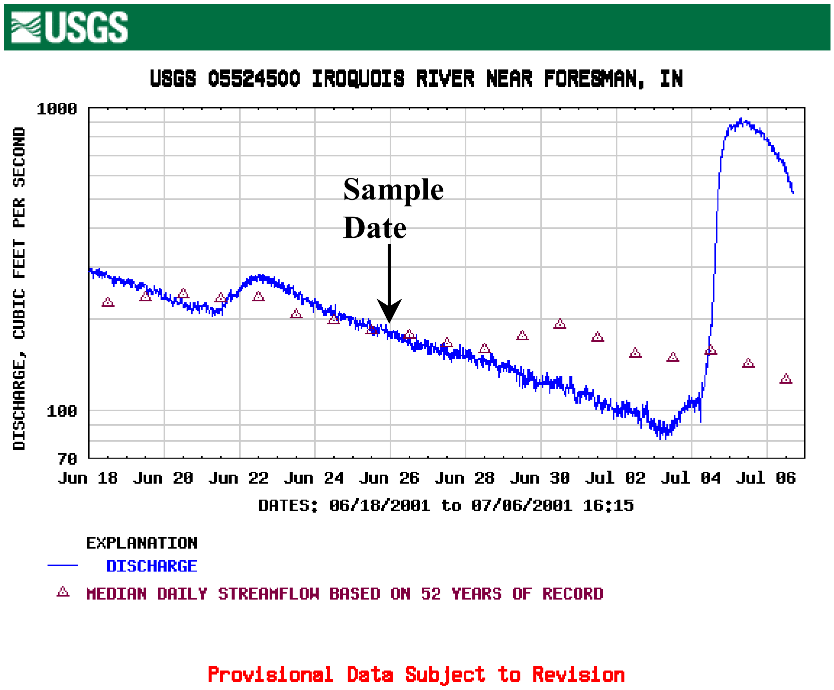

FIGURE 33. Mean daily discharge in a nearby river with base flow sampling date noted. Discharge on the sampling date equaled the 52-year median stream flow.

Base flow and stormwater runoff sampling included measurements of physical, chemical, and bacteriological parameters. Conductivity, temperature, and dissolved oxygen were measured *in situ* at each stream site with an YSI Model 85 meter. (Alkalinity was measured during base flow only.) Water velocity was measured using a Marsh-McBirney Flo-Mate current meter. Cross-sectional area of the stream channel at each site was measured and discharge calculated by multiplying water velocity by the cross-sectional areas. In addition, water samples were collected from just below the water surface using a cup sampler for the following parameters:

- pH
- alkalinity (during base flow only)
- total phosphorus (TP)
- soluble reactive phosphorus (SRP)
- nitrate-nitrogen (NO_3^-)
- ammonia-nitrogen (NH_3)
- total Kjeldahl nitrogen (TKN)
- total suspended solids (TSS)
- *E. coli* bacteria

Following collection, samples were stored in an ice chest until analysis either in the Indiana University School of Public and Environmental Affairs (IUSPEA) laboratory in Bloomington (for the base flow samples) or at Environmental Laboratories, Inc. in Madison. All sampling techniques and laboratory analytical methods were performed in accordance with procedures in *Standard Methods for the Examination of Water and Wastewater, 20th Edition* (APHA, 1998). Appendix 6 provides copies of laboratory reports for the samples.

The comprehensive evaluation of watersheds requires collecting data on the different water quality parameters listed above. A brief description of each parameter follows:

Temperature Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. Likewise, water temperature regulates the species composition and activity of life associated with the aquatic environment. Since essentially all aquatic organisms are 'cold-blooded' the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (EPA, 1976). The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits to protect aquatic life for Indiana streams. Temperatures during the month of May should not exceed 80°F (23.7°C) by more than 3°F (1.7°C). June temperatures should not exceed 90°F (32.2°C). The code also states that "the maximum temperature rise at any time or place…shall not exceed 5°F (2.8°C) in streams…"

Dissolved Oxygen (DO) DO is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3-5 parts per million (ppm) of DO. Cold-water fish, such as trout, generally require higher concentrations of DO than warm water fish like bass or bluegill. The IAC sets minimum DO concentrations at 6 mg/1 for cold-water fish. DO enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with DO. Waterbodies overloaded with algae and macrophytes often exhibit supersaturation due to high levels of photosynthesis. Rapid photosynthetic rates produce even more plant material, and low dissolved oxygen conditions can result when the plants die and bacteria consume oxygen to decompose the material. Bacterial decomposition completes the positive feedback loop by mineralizing or releasing nutrients resulting in plant growth and production. Dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1995). During low discharge, conductivity is higher than during storm water runoff because the water moves more slowly across or through ion containing soils and substrates during base flow. Carbonates and other charged particles (ions) dissolve into the slow-moving water, thereby increasing conductivity measurements.

pH The pH of stream water describes the concentration of acidic ions (specifically H^+) present in the water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6-9 pH units for the protection of aquatic life.

Alkalinity Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances, if present in water, like carbonates, bicarbonates, and sulfates can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH. During base flow conditions, alkalinity is usually high because the water picks up carbonates from the bedrock. Alkalinity measurements are usually lower during storm flow conditions because buffering compounds are diluted by rainwater, and the runoff water moves quickly across carbonate-containing bedrock materials so quickly that little carbonate is dissolved to add additional buffering capacity.

Turbidity Turbidity (measured in Nephelometric Turbidity Units) is a measure of water coloration and particles suspended in the water itself. It is generally related to suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. According to the Hoosier Riverwatch, the average turbidity of an Indiana stream is 11 NTU with a typical range of 4.5-17.5 NTU (White, unpublished data). Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978).

Nitrogen Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of the air we breathe is nitrogen gas. This nitrogen can diffuse into water where it can be "fixed", or converted, by blue-green algae to ammonia for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to aquatic systems. The three common forms of nitrogen are:

Nitrate-Nitrogen (NO_3^--N) – Nitrate is an oxidized form of dissolved nitrogen that is converted to ammonia by algae. It is found in streams and runoff when dissolved oxygen is present, usually in the surface waters. Ammonia applied to farmland is rapidly oxidized or converted to nitrate and usually enters surface and groundwater as nitrate. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams that support modified warmwater habitat (MWH) was 1.6 mg/1. Modified warmwater habitat was defined as: aquatic life use assigned to streams that have irretrievable, extensive, man-induced modification that preclude attainment of the warmwater habitat use (WWH) designation; such streams are characterized by species that are tolerant of poor chemical quality (fluctuating dissolved oxygen) and habitat conditions (siltation, habitat amplification) that often occur in modified streams (Ohio EPA, 1999). Nitrate concentrations exceeding 10 mg/1 in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6).

Ammonia-Nitrogen (NH_3-N) – Ammonia is a form of dissolved nitrogen that is the preferred form for algal use. Bacteria produce ammonia as they decompose dead plant and animal matter. Ammonia is the reduced form of nitrogen and is found in water where dissolved oxygen is lacking. Important sources of ammonia include fertilizers and animal manure. Both temperature and pH govern the toxicity of ammonia for aquatic life. According to the IAC, maximum unionized ammonia concentrations within the temperature and pH ranges measured for the study streams should range between approximately 0.13 and 0.22 mg/1.

Organic Nitrogen (Org N) – Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. In the analytical procedures, total Kjeldahl nitrogen (TKN) was analyzed. Organic nitrogen is TKN minus ammonia.

Phosphorus Phosphorus is an essential plant nutrient, and the one that most often controls aquatic plant (algae and macrophyte) growth. It is found in fertilizers, human and animal wastes, and yard waste. There are few natural sources of phosphorus to streams other than that which is attached to soil particles; there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a ***limiting nutrient*** in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Therefore, management efforts often focus on reducing phosphorus inputs to receiving waterways because: (a) it can be managed and (b) reducing phosphorus can reduce algal production. Two common forms of phosphorus are:

Soluble reactive phosphorus (SRP) – SRP is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae themselves. Because phosphorus is cycled so rapidly through biota, SRP concentrations as low as 0.005 mg/l are enough to maintain eutrophic or highly productive conditions in lake systems (Correll, 1998). Sources of SRP include fertilizers, animal wastes, and septic systems.

Total phosphorus (TP) – TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.03 mg/1 (or 30µg/1) can cause algal blooms. TP is often a problem in agricultural drainages because TP concentrations for eutrophication control are an order of magnitude lower than those typically measured in soils used to grow crops (0.2-0.3 mg/l). The Ohio EPA (1999) found that the median TP in wadeable streams that support MWH for fish was 0.28 mg/1.

Total Suspended Solids (TSS) A TSS measurement quantifies all particles suspended and dissolved in stream water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in stream water. In general, the concentration of suspended solids is greater during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. Although the State of Indiana sets no standard for TSS, total dissolved solids should not exceed 750 mg/l. In general, TSS concentrations >80 mg/1 have been found to be deleterious to aquatic life (Waters, 1995).

***E. coli* Bacteria** *E. coli* is one member of a group of bacteria that comprise the fecal coliform bacteria group and is used as an indicator organism to identify the potential for the presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235-colonies/100 ml in any one sample within a 30-day period. A study conducted by students at IU SPEA in the spring of 2000 found average fecal coliform levels of <200 colonies/100 ml in unglaciated, gravel-bottom creeks in the Stephen's Creek Watershed in Monroe County, Indiana (Klumpp et al., 2000). In general, fecal coliform bacteria have a die-off rate of 90% in 3-5 days (Gerba and McLeod, 1992). Sherer et al. (1992) found that fecal coliform bacteria lived an average of 17 days longer when incubated with sediment. Additionally, benthic sediments can harbor significantly higher concentrations of bacteria than the overlying water and disturbance of the sediment can result in contamination of the water column.

Water Chemistry Results

Introduction

There are two useful ways to report water quality data in flowing water. *Concentrations* describe the mass of a particular material contained in a unit of water, for example, milligrams of phosphorus per liter (mg/l). *Mass loading* (in units of kg/day) on the other hand describes the mass of a particular material being carried per unit of time. For example, a high concentration of phosphorus in a stream with very little flow will deliver a smaller total amount of phosphorus to the receiving waterway than will a stream with a low concentration of phosphorus but a high flow of water. It is the total amount (mass) of phosphorus, solids, and bacteria actually delivered from the watershed that is the most important when considering the effects of these materials downstream. Because consideration of concentration and mass loading data is important, the following three sections will discuss 1) physical parameter concentrations, 2) chemical and bacterial parameter concentrations, and 3) chemical and sediment parameter mass loading.

Physical Parameter Concentrations

Physical parameter results measured during base and storm flow sampling are presented in Table 48. Stream discharges measured during base and storm flow conditions are shown in Figure 34. Each physical parameter is addressed in the following discussion.

TABLE 48. Physical parameter data collected during stream chemistry sampling events in the Mud Pine Creek Watershed on 5/18/2001 and 6/26/2001.

Site	Date	Timing	Flow (cfs)	Temp. °C	D.O. (mg/l)	D.O. Sat. (%)	Cond. (μmhos)	pH	Alk. (mg/l)	Turbidity (NTU)
1	5/18/2001	Storm	6.68	21	7	78.5	310	6.8	*	1.0
	6/26/2001	Base	2.81	22.9	17.24	204.0	706	8.8	213	1.4
2	5/18/2001	Storm	4.63	17.5	7.4	77.4	400	6.8	*	<1.0
	6/26/2001	Base	1.48	21.0	13.48	151.9	662	7.8	225	1.6
3	5/18/2001	Storm	0.57	21	10	112.2	360	6.9	*	2.0
	6/26/2001	Base	0.36	20.1	8.36	92.3	602	7.8	213	2.9
4	5/18/2001	Storm	7.52	18.5	9.8	104.6	320	6.9	*	1.0
	6/26/2001	Base	1.46	20.5	7.29	80.9	621	7.9	227	4.3
5	5/18/2001	Storm	13.15	18.5	8.4	89.6	220	6.8	*	<1.0
	6/26/2001	Base	5.04	21.4	14.81	168.1	669	8.4	213	1.5
6	5/18/2001	Storm	61.36	18.5	9.4	100.3	360	6.9	*	5.0
	6/26/2001	Base	9.91	21.6	8.33	92.9	651	8	210	1.8
7	5/18/2001	Storm	58.80	17	9	93.1	420	6.9	*	8.0
	6/26/2001	Base	3.37	18.8	8.27	88.3	623	7.8	241	2.0
8	5/18/2001	Storm	188.69	17	10	103.5	400	6.8	*	16.0
	6/26/2001	Base	19.01	23.4	7.40	88.6	654	8	215	9.2

*= Alkalinity was only sampled during the base flow event.

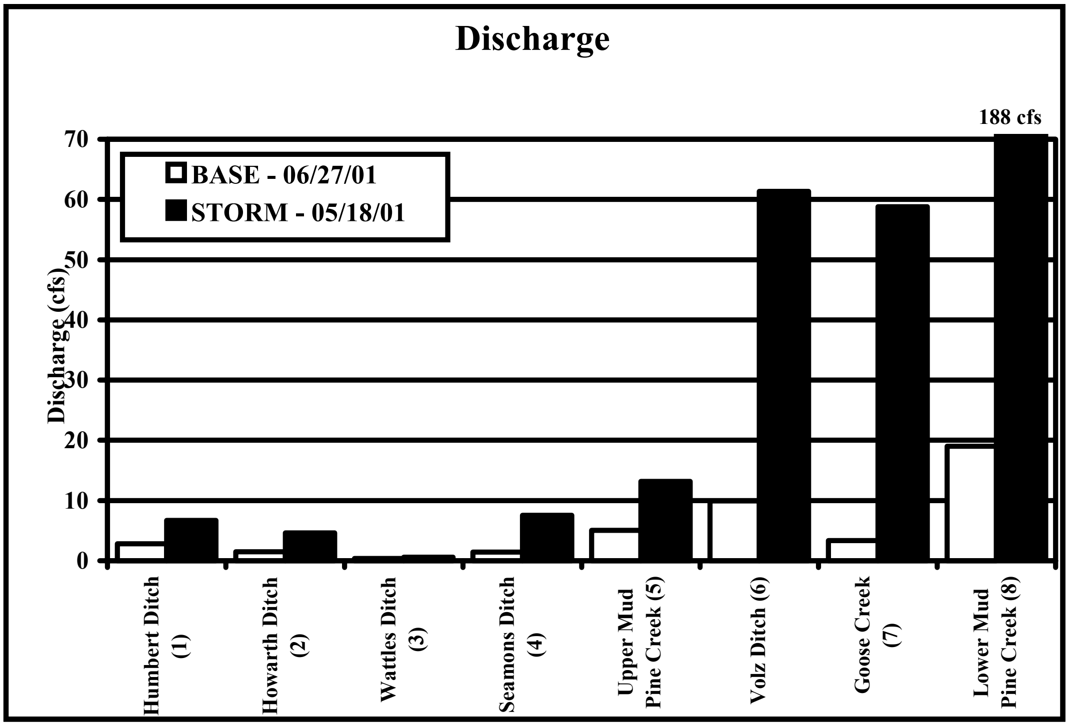

FIGURE 34. Discharge or flow measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

During base flow conditions, temperatures in the creeks varied from 18.8°C (65.8°F) in Goose Creek (Site 7) to 23.4°C (74.1°F) in Lower Mud Pine Creek (Site 8). Water temperatures during stormflow varied from 17°C (62.6°F) in Goose Creek (Site 7) and Mud Pine Creek (Site 8) to 21°C (69.8°F) in Humbert Ditch (Site 1) and Wattles Ditch (Site 3). All temperatures were within ranges suitable for aquatic life. Those creeks with cooler temperatures, such as the upper tributaries, likely had a greater proportion of groundwater flowing in them. Streamside vegetation that provides shading to the water can also prevent heat gain. The higher temperatures measured in some streams are likely due to small size, lack of riparian shading, lower proportion of groundwater inputs, and/or point source inputs (like the Fowler Municipal Wastewater Treatment Plant (WWTP) that discharges treated effluent to Humbert Ditch).

Dissolved oxygen (DO) concentrations varied from 7 mg/l to 17.24 mg/l. Because DO varies with temperature (cold water can contain more oxygen than warm water), it is relevant to consider DO saturation values. This refers to the amount of oxygen dissolved in water compared to the maximum possible when water is in equilibrium with the atmosphere and is saturated with oxygen. The 100% saturation value of water at 18°C is 9.5 mg/l. Stream dissolved oxygen concentrations that are less than 100% saturation suggest that: a) decomposition processes within the stream consume oxygen more quickly than it can be replaced by diffusion from the atmosphere, and b) flow in the streams is not turbulent enough to entrain sufficient oxygen. Stream data indicate that saturated dissolved oxygen conditions occurred in stream water at several sites during both base and storm flows (Table 48). DO saturation averaged 88% during base flow and 95% during stormflow. Under-saturated water in streams means that significant respiration, likely caused by bacteria decomposing dissolved and particulate organic matter, is consuming oxygen faster than the flowing water can replace it by turbulent mixing. DO in all streams exceeded the Indiana state minimum standard of 6 mg/l indicating that oxygen was sufficient to support aquatic life. Some dissolved oxygen concentrations were high (14-17 mg/L) indicating supersaturation which can be caused by excessive algal growth usually in response to high nutrient concentrations. The data suggest algal and macrophyte overproductivity at Sites 1, 2, and 5 during baseflow conditions.

Conductivity in Upper Mud Pine Creek Watershed streams ranged from 220 μmhos in Upper Mud Pine Creek (Site 5) to 420 μmhos in Goose Creek (Site 7) during storm water runoff and from 602 μmhos in Wattles Ditch (Site 3) to 706 μmhos in Humbert Ditch (Site 1) during base flow. Conductivity during low discharge was generally higher than conductivity during storm sampling. High flows tend to dilute charge-bearing ions and allow little time for ion dissolution into the water from the soil.

Values of pH were well within the range of 6-9 units established by the Indiana Administrative Code (IAC). pH levels during base flow were generally greater (7.8-8.8) than levels measured during storm flow conditions (6.8-6.9). During low water periods, stream water has more time to accrue buffering compounds from alkaline soils. Alkalinity measurements taken during base flow conditions indicate that Mud Creek watershed streams are well buffered.

During high periods of flow, turbidity is generally greater than during low flow conditions because increased overland flow during and following storms can erode soil and carry it to the stream. Volz Ditch (Site 6), Goose Creek (Site 7) and Lower Mud Pine Creek (Site 8) became noticeably more turbid during storm sampling. Turbidity measurements during storm flow were slightly lower than those measured during base flow for all remaining sites. This result suggests that stormwater runoff high in the watershed does not carry significant amounts of dissolved or suspended solids.

Chemical and Bacterial Parameter Concentrations

Chemical and bacterial concentration data for Upper Mud Pine Creek Watershed streams are listed by site in Table 49. Figures 35-42 present concentration information graphically.

TABLE 49. Chemical and bacterial data collected during stream chemistry sampling events in the Upper Mud Pine Creek Watershed on 5/18/2001 and 6/26/2001.

Site	Date	Timing	NO_3^- (mg/l)	NH_3 (mg/l)	TKN (mg/l)	SRP (mg/l)	TP (mg/l)	TSS (mg/l)	*E. coli* (col/100 ml)
1	5/18/2001	Storm	0.900	0.8	2.3	0.016	0.511	9	250
	6/26/2001	Base	12.442	0.053	0.230*	0.198	0.223	1.867	190
2	5/18/2001	Storm	0.900	0.8	2.2	0.014	0.415	8	200
	6/26/2001	Base	11.828	0.018*	0.477	0.014	0.025	1.074	70
3	5/18/2001	Storm	1.000	0.9	2.6	0.015	0.52	6	220
	6/26/2001	Base	9.775	0.018*	0.230*	0.009	0.039	4.667	310
4	5/18/2001	Storm	1.000	0.8	2.3	0.013	0.465	8	300
	6/26/2001	Base	11.126	0.037	0.230*	0.005	0.019	6.4	300
5	5/18/2001	Storm	0.440	0.6	1.9	0.011	0.46	9	330
	6/26/2001	Base	10.903	0.018*	0.230*	0.089	0.107	0.933	240
6	5/18/2001	Storm	0.360	1	2.6	0.011	0.38	7	300
	6/26/2001	Base	11.163	0.018*	0.230*	0.026	0.045	2.133	220
7	5/18/2001	Storm	1.000	1	2.5	0.012	0.395	8	220
	6/26/2001	Base	10.026	0.018*	0.230*	0.026	0.045	2.267	350
8	5/18/2001	Storm	0.300	0.9	2.3	0.011	0.39	7	260
	6/26/2001	Base	9.928	0.018*	0.230*	0.018	0.068	21.75	240

* Method Detection Limit

Nitrate-nitrogen concentrations in the Upper Mud Pine Creek Watershed streams are illustrated in Figure 35. Nitrate-nitrogen concentrations at every site during base flow conditions exceeded 1.6 mg/l, the median nitrate-nitrogen concentration of wadeable streams found by the Ohio EPA (1999) to support modified warmwater habitat (MWH). All sites except for Wattles Ditch (Site 3) and Lower Mud Pine Creek (Site 8) exceeded the IAC standard of 10 mg/l during base flow conditions. Base flow nitrate-nitrogen concentrations were higher than storm flow concentrations at every site. Possible reasons for this include: 1) baseflow sampling occurred during the receding period of the hydrograph (Figure 33) when streamflow is more strongly influenced by shallow subsurface flow called interflow. Interflow can carry higher concentrations of dissolved nutrients due to longer soil-water contact time. Because many of the streams are drainage ditches managed to drain shallow groundwater from fields, the influence of interflow could be even greater during a receding hydrograph; 2) recent field fertilization with ammonia followed by soil nitrification processes may have resulted in high soil nitrogen concentrations. Nitrate which is highly water-soluble could have been easily transported via interflow (University of Arkansas, 1993); 3) stormwater runoff as overland flow typically contains less nitrate. Overland flow could have diluted interflow contribution resulting in lower stormflow stream nitrate concentrations.

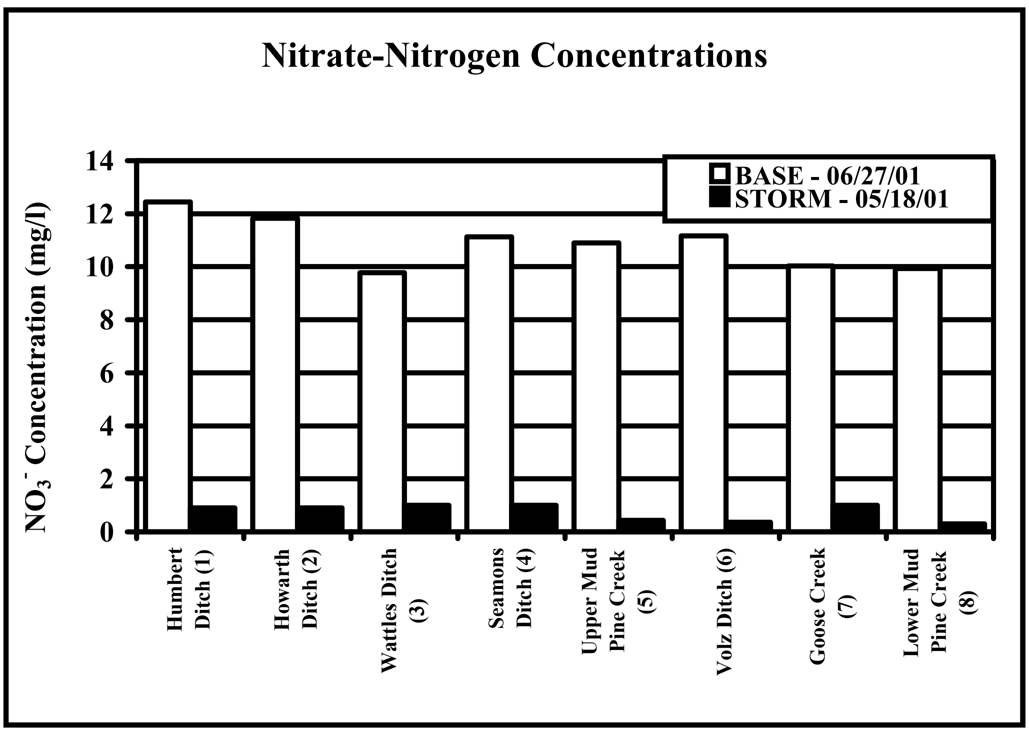

FIGURE 35. Nitrate-nitrogen concentration measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

Ammonia-nitrogen concentrations during base flow (Figure 36) generally fell within the range (0.13-0.22 mg/l) set by the IAC for the protection of aquatic life. (The standard is a range because it is based upon temperature and pH). Humbert Ditch (Site 1) and Seamons Ditch (Site 4) were the only stream reaches to register a base flow concentration above the detection limit (0.018 mg/l). Storm flow ammonia-nitrogen exceeded the IAC standard range at all sites; concentrations measured 0.6-1.0 mg/l. High rates of runoff during storms can wash ammonia from farm fields and livestock areas into the streams.

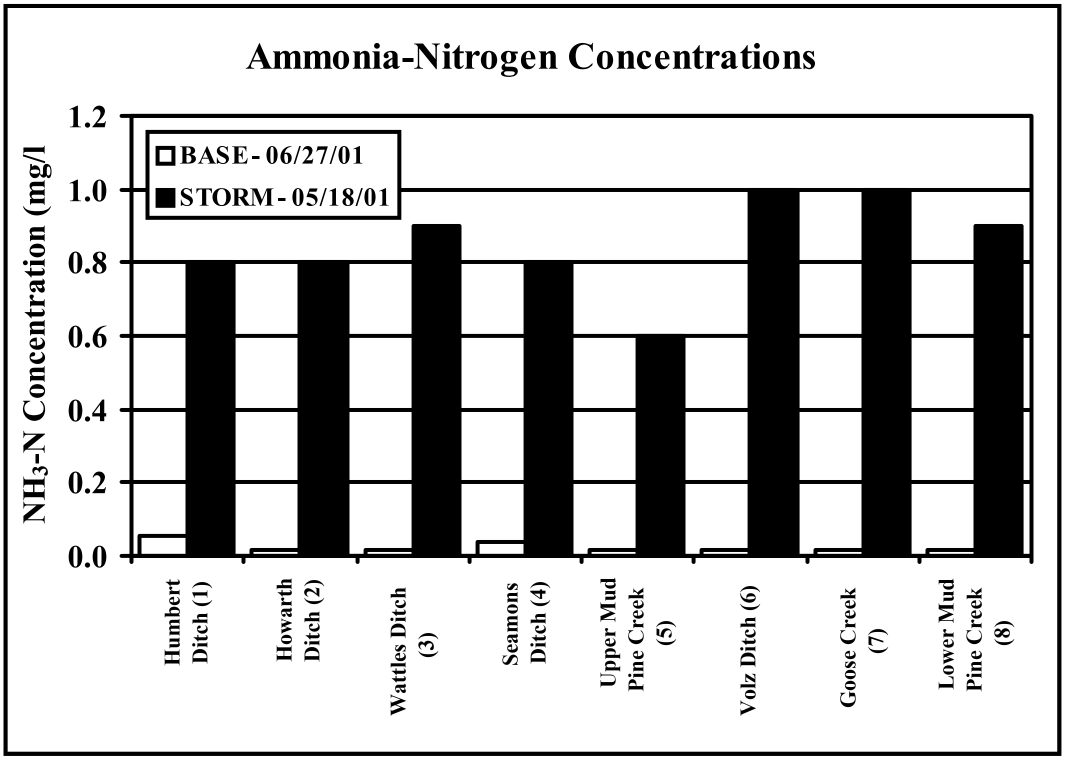

FIGURE 36. Ammonia-nitrogen concentration measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

Total Kjeldahl nitrogen (TKN) concentrations measured in streams were also elevated during storm flows (Figure 37). The storm flow concentrations ranged from 1.9-2.6 mg/l, while all base flow concentrations except Howarth Ditch (Site 2) fell below the detection limit of 0.23 mg/l.

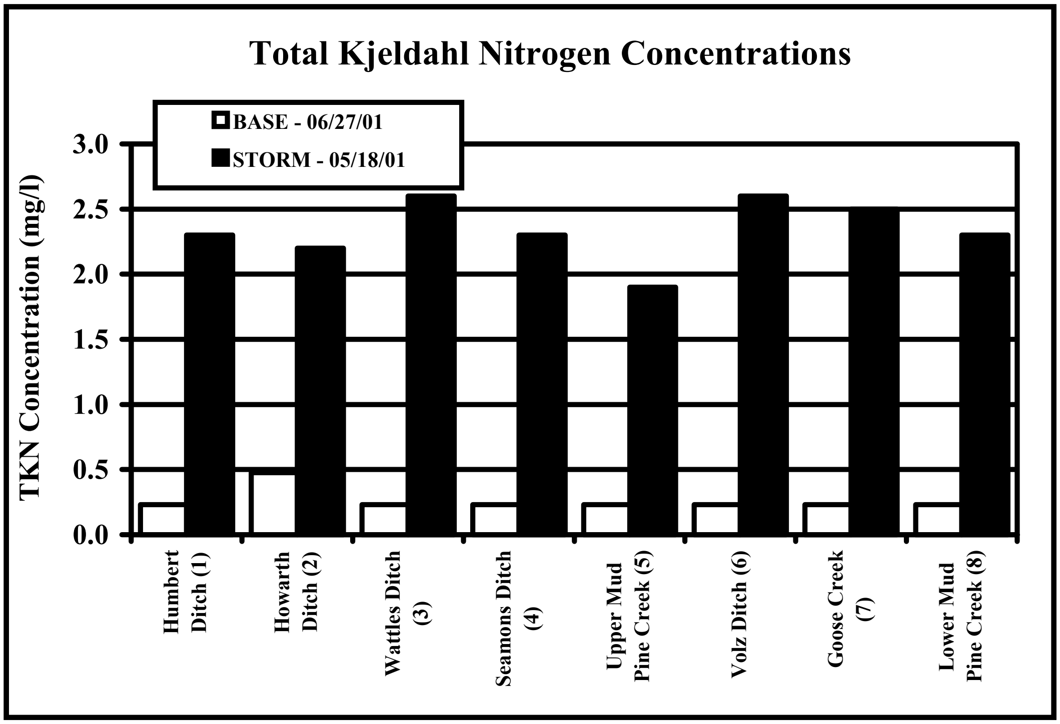

FIGURE 37. Total Kjeldahl nitrogen (TKN) concentration measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

All storm event and base flow concentrations of soluble reactive phosphorus (SRP) fell below the minimum level that prevents overproductivity in aquatic systems (Figure 38) except Humbert Ditch (Site 1) and Upper Mud Pine Creek (Site 5) during base flow conditions. SRP concentrations at these sites were significantly elevated. The high SRP concentration measured in Humbert Ditch may be due in part to Fowler WWTP discharge. During low flow conditions, samples from most subwatersheds revealed that the soluble fraction was >50% of the total phosphorus (TP), suggesting that a majority of the phosphorus loading was soluble, not particulate or soil-associated (Figure 39). However, during storm flow SRP was <5% of TP at all sites. Elevated particulate phosphorus loading during storms is indicative of soil loss via erosion since particulate phosphorus is typically adsorbed to soil particles.

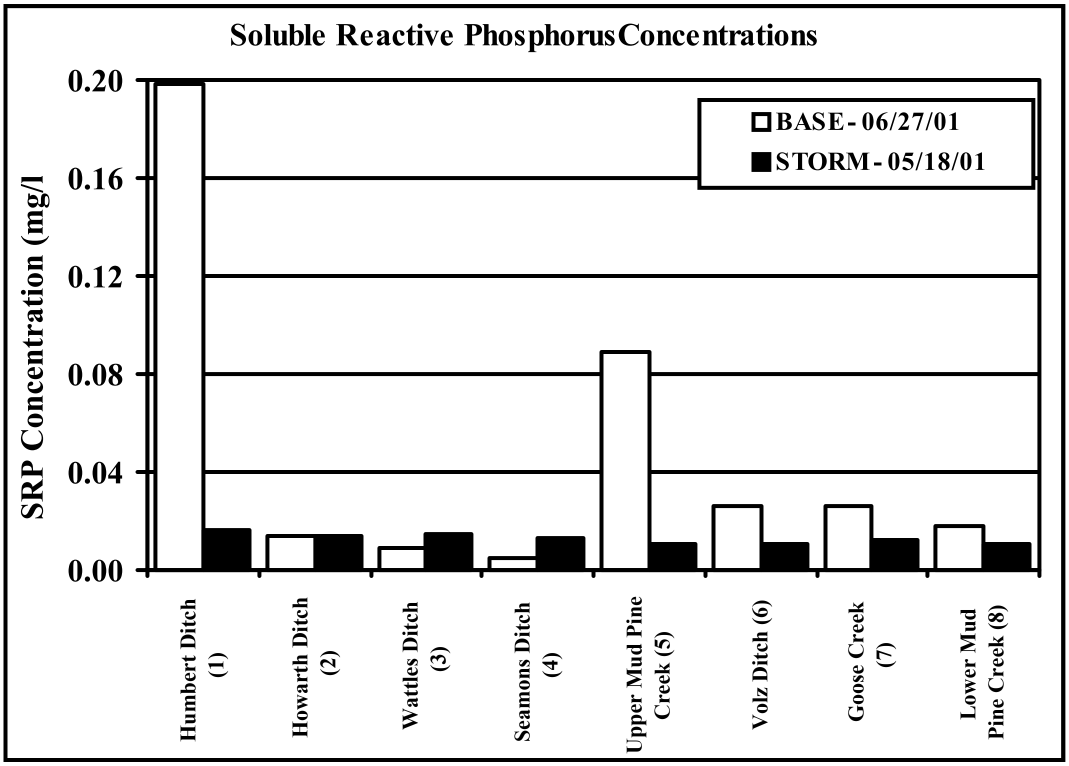

FIGURE 38. Soluble reactive phosphorus (SRP) concentration measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

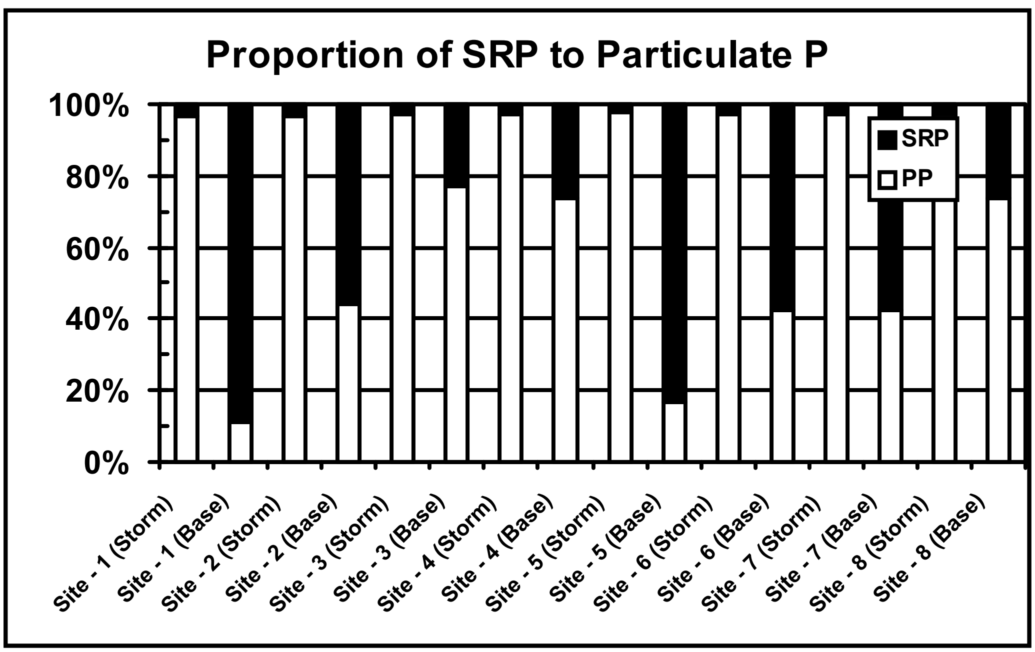

FIGURE 39. Soluble reactive phosphorus (SRP) percentage of total phosphorus (TP) concentration measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams. TP concentration minus SRP concentration yields an estimation of particulate phosphorus (PP).

Total phosphorus (TP) concentrations in storm water samples (Figure 40) were notably elevated at all sites. TP levels were 13-17 times the minimum level that causes eutrophication of temperate water bodies (0.03 mg/l). During base flow, all sites except Howarth Ditch (Site 2) and Seamons Ditch (Site 4) exceeded the eutrophication level, but no site exceeded the 0.28 mg/l level acceptable for modified warmwater habitat (Ohio EPS, 1999).

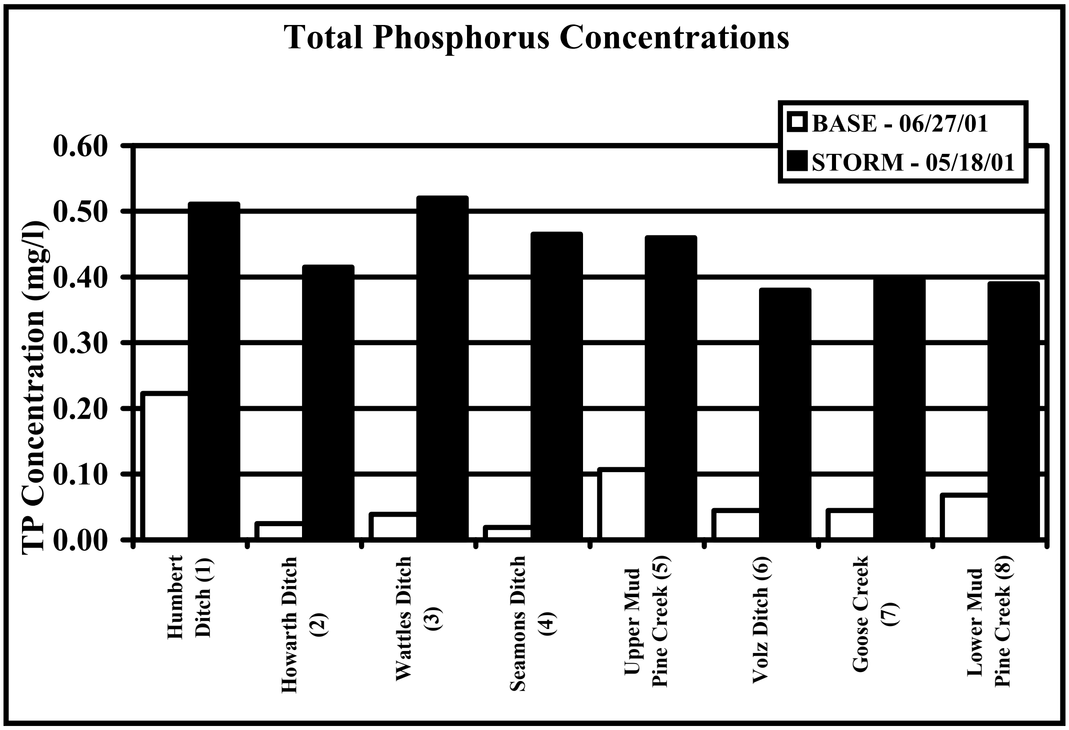

FIGURE 40. Total phosphorus (TP) concentration measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

In general, total suspended solid (TSS) concentrations were greater during storm flow conditions than during base flow conditions (Figure 41). TSS concentrations did not exceed levels known to be deleterious to aquatic life (80 mg/l) during base flow or storm flow conditions (Waters, 1995). The researchers who collected baseflow samples suspect that a localized disturbance (such as livestock in the water upstream) caused the elevated TSS measurement at Site 8 on Mud Pine Creek.

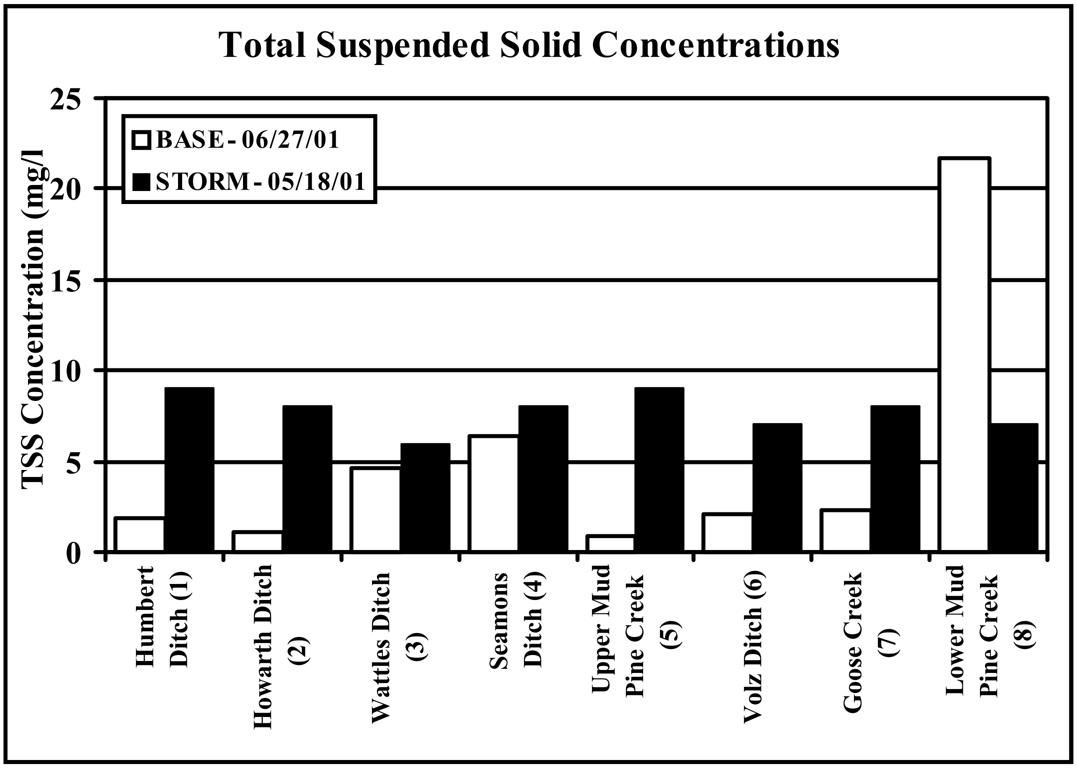

FIGURE 41. Total suspended solid (TSS) concentration measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

When compared to many agricultural watersheds in Indiana, *E. coli* concentrations were low in the Upper Mud Pine Creek Watershed (Figure 42). During storm flows, Howarth Ditch (Site 2), Wattles Ditch (Site 3), and Goose Creek (Site 7) did not exceed the Indiana state standard of 235 col/100ml, and all other sites exceeded the standard only slightly by an average of 53 col/100ml. Storm flow concentrations in violation ranged from 250 col/100 ml in Humbert Ditch (Site 1) to 330 col/100 ml in Upper Mud Pine Creek (Site 5). Base flow samples only exceeded the state standard by an average of 5 col/100ml and ranged from 70 col/100 ml at Howarth Ditch (Site 2) to 350 col/100ml at Goose Creek (Site 7).

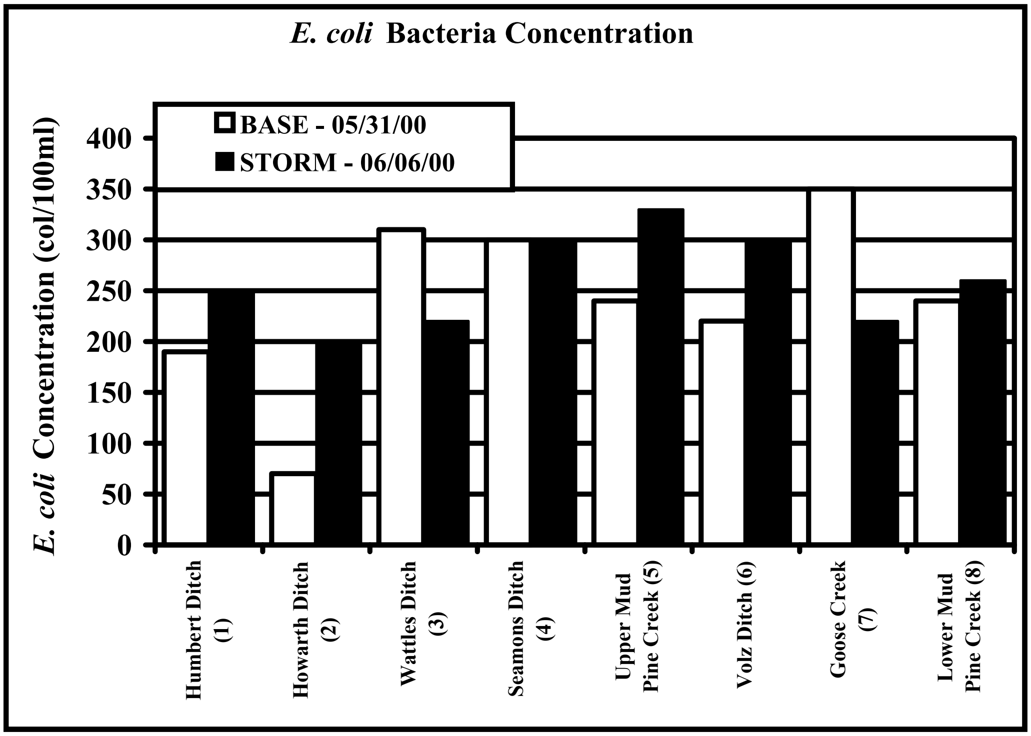

FIGURE 42. *E. coli* bacteria concentration measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

Sediment and Chemical Parameter Mass Loading

Nutrient and sediment loading from streams in the Upper Mud Pine Creek Watershed were generally governed by flow rate (i.e. streams with higher rates of flow also contributed higher nutrient and sediment loads). Table 50 summarizes sampling locations that loaded disproportionate amounts for the various parameters relative to discharge rate (i.e., these streams loaded more nutrients and/or sediment despite having smaller discharges than other streams where data was collected. Nitrate-nitrogen loading was governed by flow rate at all sites except Goose Creek (Site 7) which contributed more nitrate-nitrogen relative to discharge (Figure 43). Ammonia and TKN loading was driven by flow rate (Figures 44 and 45). Phosphorus was the parameter least driven by flow rate. Humbert Ditch (Site 1), Upper Mud Pine Creek (Site 5), and Goose Creek (Site 7) contributed significantly to SRP loading despite having relatively small flows (Figure 46). TP loading (Figure 47) was also disproportional to flow rate for Humbert Ditch (Site 1), Upper Mud Pine Creek (Site 5), and Seamons Ditch (Site 4). Lower Mud Pine Creek (Site 8) and Goose Creek (Site 7) carried larger amounts of suspended solids relative to rate of discharge, suggesting that these subwatershed areas had detectibly higher sediment loss rates (Figure 48). Sediment loading rates were variable but high at some sites ranging from 3 to 3,232 kg/day (7 to 7,127 lbs/day) depending on flow regime and location.

TABLE 50. Streams that loaded disproportionate amounts of the various parameters relative to discharge rate.

Site	Parameter	Event
Goose Creek (Site 7)	NO_3^--N	Storm
Humbert Ditch (Site 1)	SRP	Base
Upper Mud Pine Creek (Site 5)	SRP	Base
Goose Creek (Site 7)	SRP	Storm
Humbert Ditch (Site 1)	TP	Base
Upper Mud Pine Creek (Site 5)	TP	Base
Humbert Ditch (Site 1)	TP	Storm
Seamons Ditch (Site 4)	TP	Storm
Lower Mud Pine Creek (Site 8)	TSS	Base
Goose Creek (Site 7)	TSS	Storm

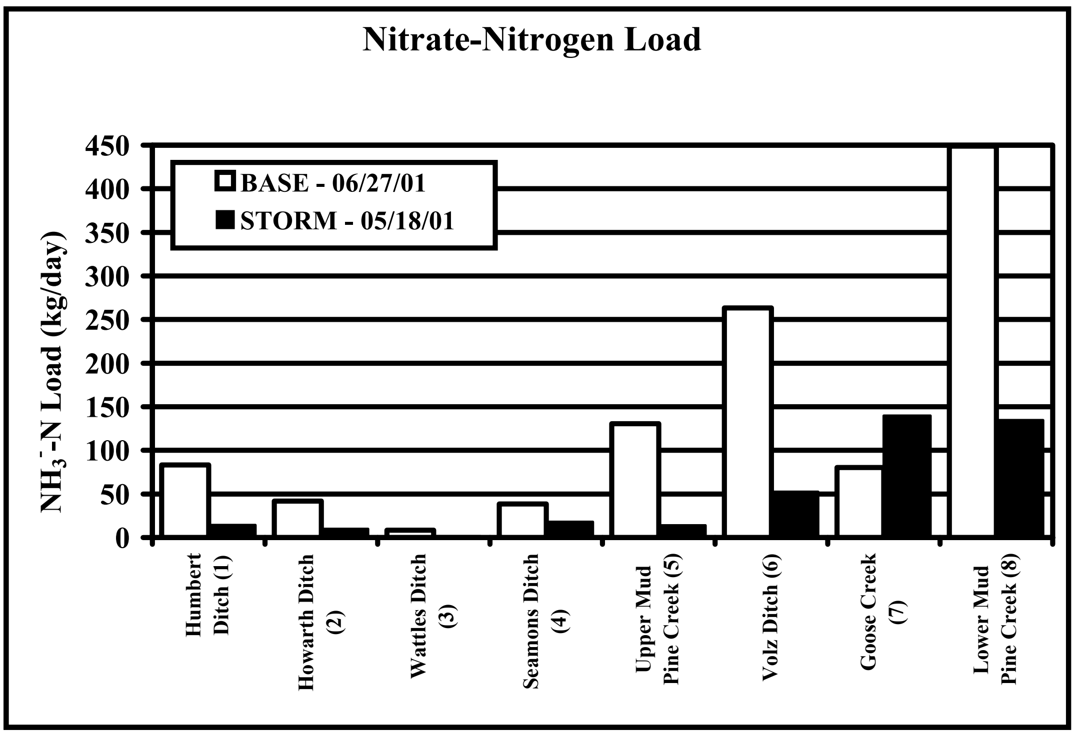

FIGURE 43. Nitrate-nitrogen loading measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

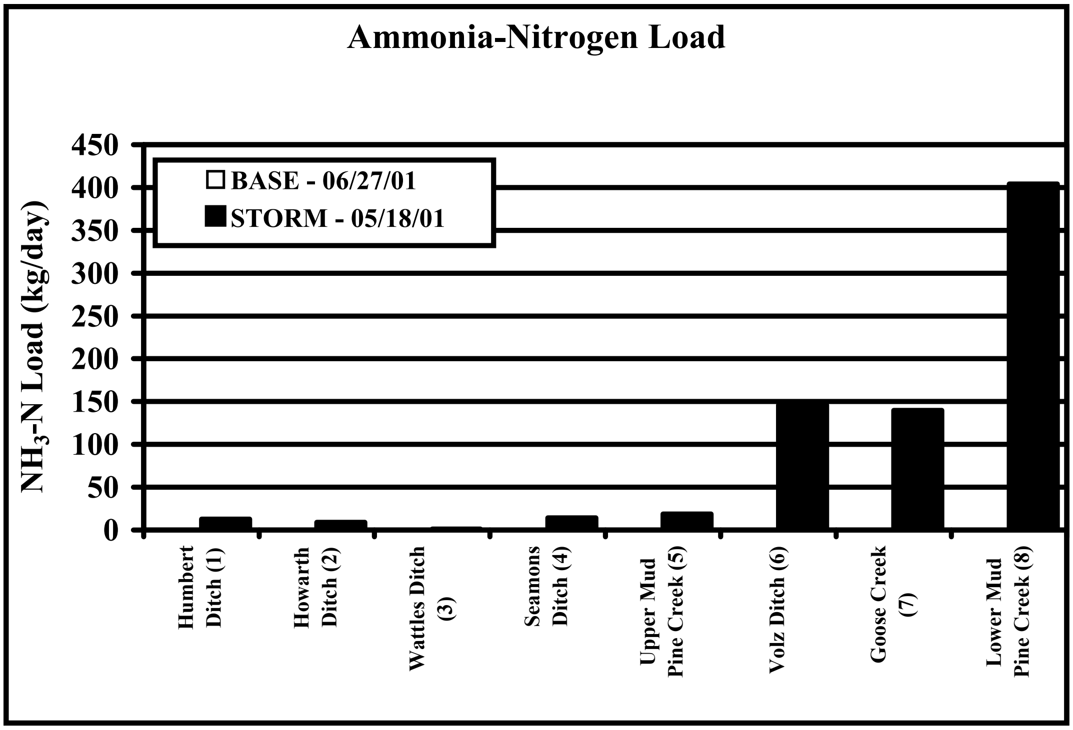

FIGURE 44. Ammonia-nitrogen loading measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

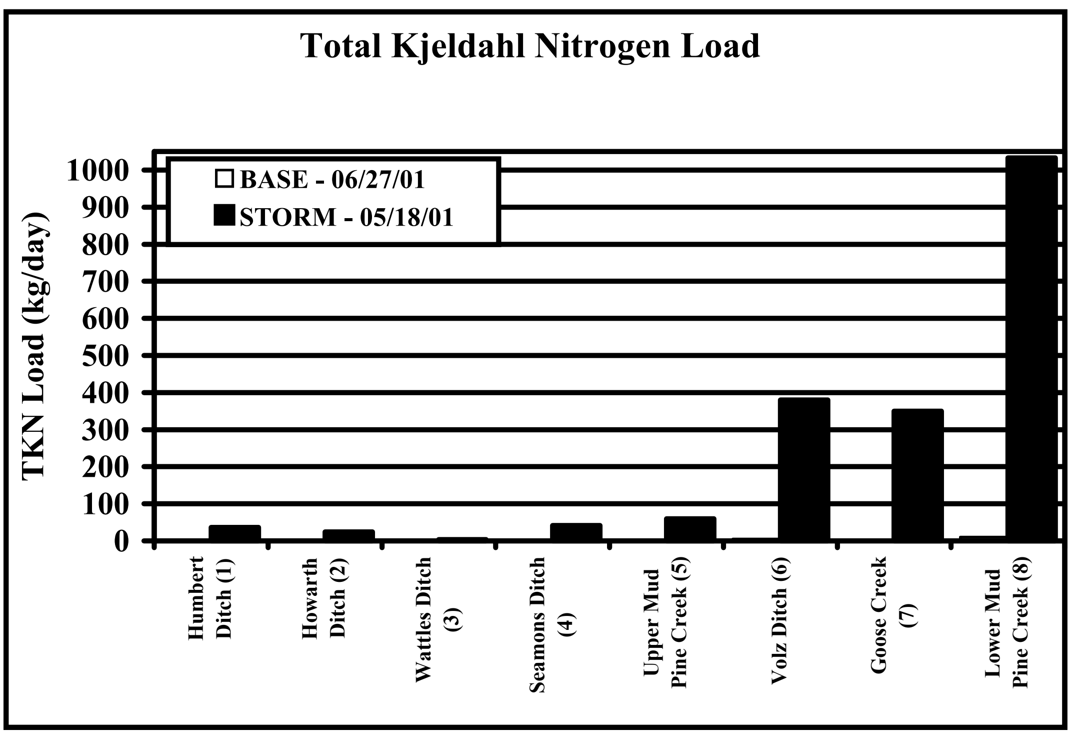

FIGURE 45. Total Kjeldahl nitrogen (TKN) loading measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

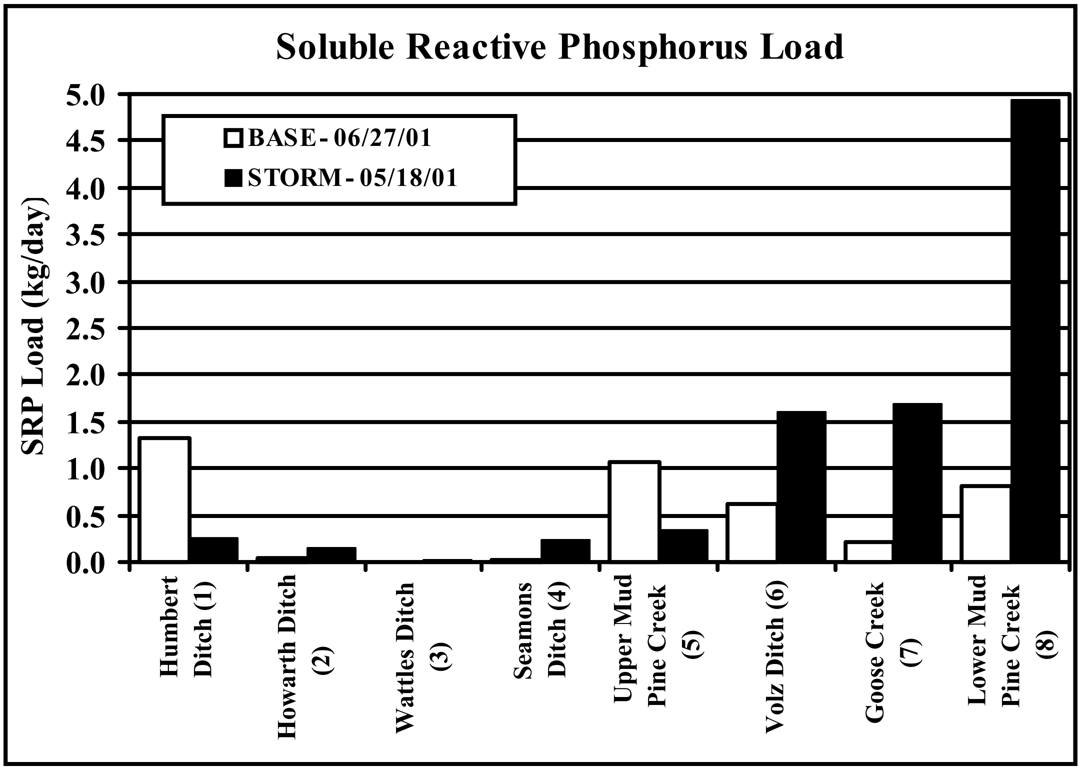

FIGURE 46. Soluble reactive phosphorus (SRP) loading measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

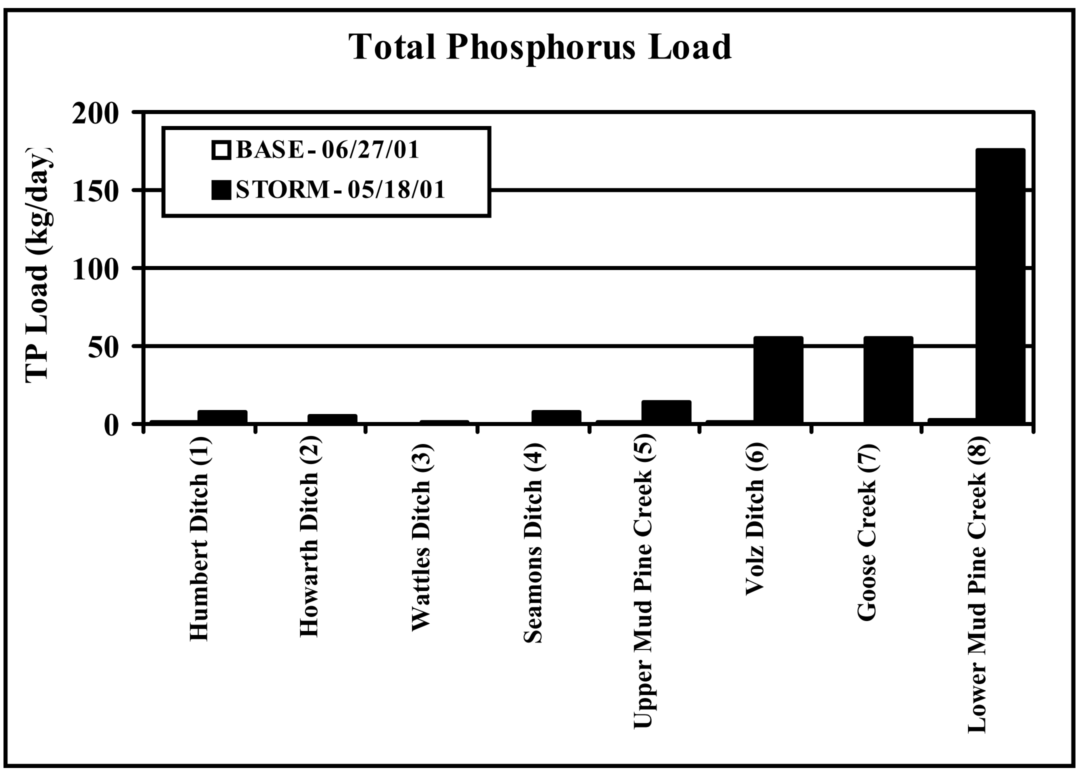

FIGURE 47. Total phosphorus (TP) loading measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

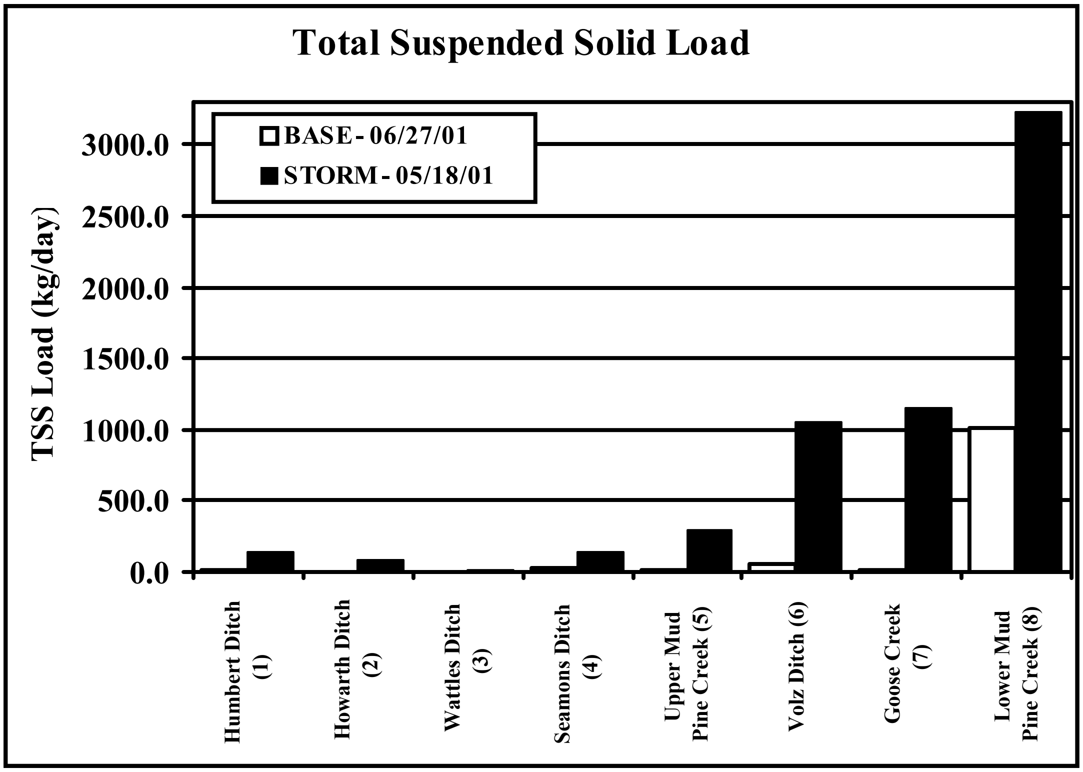

FIGURE 48. Total suspended solids (TSS) loading measurements during base flow and storm flow sampling of Upper Mud Pine Creek Watershed streams.

Water Chemistry Discussion

In an effort to normalize the sediment, nutrient, and bacteria loading rates, the rates were divided by subwatershed size above each sampling site. Sampling sites in certain subwatersheds received loading from adjacent subwatersheds. In these cases, loads from adjacent subwatersheds were subtracted from the subwatershed of consideration. Table 51 shows sample sites representing the respective subwatersheds, and Table 52 shows the results of this analysis.

TABLE 51. Sampling sites representing subwatersheds within the study area.

Watershed/Subwatershed	Sampling Site(s)
Humbert Ditch Subwatershed	1
Howarth Ditch Subwatershed	2
Wattles Ditch Subwatershed	3
Seamons Ditch Subwatershed	4
Upper Mud Pine Creek Subwatershed	=5-3-2-1
Volz Ditch Subwatershed	=6-5-4
Goose Creek Subwatershed	7
Lower Mud Pine Creek Subwatershed	=8-7-6

TABLE 52. Areal loading of TSS, TP, and *E. coli* by subwatershed based on the base flow and storm flow sampling events.

Watershed/Subwatershed	Watershed Size	Timing	TSS Load (kg/ha/yr)	TP Load (kg/ha/yr)	*E. coli* Load (millions of col/ha/yr)
Humbert Ditch	5859 ac (2372 ha)	base	3.28	0.38	114.63
Humbert Ditch	5859 ac (2372 ha)	storm	37.60	2.08	358.56
Howarth Ditch	3456 ac (1399 ha)	base	1.06	0.02	23.70
Howarth Ditch	3456 ac (1399 ha)	storm	24.69	1.25	211.87
Wattles Ditch	1299 ac (526 ha)	base	1.40	0.01	31.98
Wattles Ditch	1299 ac (526 ha)	storm	2.85	0.24	35.93
Seamons Ditch	3729 ac (1510 ha)	base	22.37	0.06	360.03
Seamons Ditch	3729 ac (1510 ha)	storm	144.05	8.14	1854.40
Upper Mud Pine Creek	3023 ac (1224 ha)	base	2.56	0.51	562.62
Upper Mud Pine Creek	3023 ac (1224 ha)	storm	143.75	6.82	2023.06
Volz Ditch	7114 ac (2880 ha)	base	-20.75	-0.79	-741.52
Volz Ditch	7114 ac (2880 ha)	storm	-151.25	-7.88	-1516.48
Goose Creek	8975 ac (3634 ha)	base	3.57	0.07	189.24
Goose Creek	8975 ac (3634 ha)	storm	219.80	10.55	2075.09
Lower Mud Pine Creek	8341 ac (3377 ha)	base	85.05	0.03	-167.36
Lower Mud Pine Creek	8341 ac (3377 ha)	storm	-106.67	-4.14	1028.13

Sediment loading was lower during low flow conditions than during stormwater for all subwatersheds. The Goose Creek Subwatershed contributed more sediment per unit area than any other subwatershed during stormwater runoff. Seamons Ditch also loaded over 100 kg/ha/yr (221 lbs/ac/yr) during storm flows. Base flow loading from Goose Creek was elevated as well. Negative loading rates indicate that Volz Ditch and Lower Mud Pine Creek served as depositional areas or net sink areas for sediment during at least some portion(s) of the hydrologic cycle. Per acre of subwatershed area, Goose Creek and Seamons Ditch contributed the greatest load of total phosphorus. Again, Volz Ditch and Lower Mud Pine Creek Subwatersheds were depositional areas or net sink areas for total phosphorus having negative areal loading rates. *E. coli* loading was worst from the Goose Creek Subwatershed which loaded as much as 2075 million col/ha/yr during storm flow conditions. Areal bacterial loading was also elevated in the Upper Mud Pine Creek and Seamons Ditch Subwatersheds. On the other hand, Lower Mud Pine

Creek and Volz Ditch were net sinks of *E. coli* bacteria during sampling periods. This net loss is probably due to death or deposition without substantial bacterial input within the reaches.

Water Chemistry Summary

In general, physical and chemical parameter data collected from streams in the Upper Mud Pine Creek Watershed indicate evidence of water quality degradation when compared with ideal conditions. Nutrient concentrations were generally higher than median nutrient concentrations observed in modified Ohio streams known to support healthy modified warmwater habitats for aquatic life. Although concentrations of most nutrients were higher during storm flows than during base flows, nitrate-nitrogen concentrations were significantly elevated during low flows possibly due to groundwater interflow and leaching potentials (Figure 16). Bacteria levels were low compared to other agricultural watersheds in Indiana. The highest *E. coli* concentration measured only 115 col/100ml greater than the Indiana state standard of 235 col/100ml. Sediment loading rates varied but were quite high at some sites ranging from 3-3232 kg/day (7-7127 lbs/day) depending on flow regime and location. While some reaches per unit area acted as net sinks for sediment, phosphorus, and bacteria others delivered significant loads of the parameters particularly during high water stage. The Goose Creek Subwatershed contributed more TSS, TP, and *E. coli* than any other subwatershed during storm conditions per unit area (Table 50). During low flow periods, Upper Mud Pine Creek dominated areal loading of TP and *E. coli*. In conclusion according to the stream chemistry data, some creeks can be classified as relatively more impaired including: Goose Creek, Humbert Ditch, Upper Mud Pine Creek, and Seamons Ditch.

Macroinvertebrates and Habitat

Macroinvertebrate Sampling Methods

Macroinvertebrate samples from each of the 8 sites were used to calculate an index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The insect community composition reflects water quality, and research shows that different macroinvertebrate orders and families react differently to pollution sources. Indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995).

Macroinvertebrates were collected during base flow conditions on July 25, 2001 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al. 1999). This method was supplemented by qualitative picks from substrate and by surface netting. Two researchers collected macroinvertebrates for 20 minutes and a third researcher aided in the collection for 10 minutes for a total of 50 minutes of collection effort. The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the same manual. Organisms were identified to the family level. The family-level approach was used: 1) to collect data comparable to that collected by the Indiana Department of Environmental Management (IDEM) from streams throughout Indiana; 2) because it allows for increased organism identification accuracy; and 3) because several studies support the adequacy of family-level analysis (Furse et al. 1984, Ferraro and Cole 1995, Marchant 1995, Bowman and Bailey 1997, Waite et al. 2000).

Macroinvertebrate data were used to calculate the family-level Hilsenhoff Biotic Index (HBI). Calculation of the HBI involves applying assigned macroinvertebrate family tolerance values to all taxa present that have an assigned HBI tolerance value, multiplying the number of organisms present by their family tolerance value, summing the products, and dividing by the total number of organisms present (Hilsenhoff 1988). A higher value on the HBI scale indicates greater impairment.

In addition to the HBI, macroinvertebrate results were analyzed by applying an adaptation of the IDEM modified Index of Biotic Integrity (mIBI) (IDEM, 1996). mIBI scores allow comparison with data compiled by IDEM for wadeable riffle-pool streams. IDEM developed the classification criteria based on five years of wadeable riffle-pool data collected in Indiana. The data were lognormally distributed for each of the metrics. Each metric's lognormal distribution was then pentasected with scoring based on five categories using 1.5 times the interquartile range around the geometric mean. Table 53 lists the eight scoring metrics used in this study with classification scores of 0-8. The mean of the eight metrics is the mIBI score. mIBI scores of 0-2 indicate the sampling site is severely impaired, scores of 2-4 indicate the site is moderately impaired, scores of 4-6 indicate the site is slightly impaired, and scores of 6-8 indicate that the site is non-impaired.

TABLE 53. Benthic macroinvertebrate scoring criteria used by IDEM in the evaluation of pool-riffle streams in Indiana.

	ADAPTED SCORING CRITERIA FOR THE FAMILY LEVEL MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (mIBI) USING PENTASECTION AND CENTRAL TENDENCY ON THE LOGARITHMIC TRANSFORMED DATA DISTRIBUTIONS OF THE 1990-1995 RIFFLE KICK SAMPLES				
		CLASSIFICATION SCORE			
	0	**2**	**4**	**6**	**8**
Family Level HBI	≥5.63	5.62- 5.06	5.05-4.55	4.54-4.09	≤4.08
Number of Taxa	≤7	8-10	11-14	15-17	≥18
Percent Dominant Taxa	≤61.6	61.5-43.9	43.8-31.2	31.1-22.2	≥22.1
EPT Index	≤2	3	4-5	6-7	≥8
EPT Count	≤19	20-42	43-91	92-194	≥195
EPT Count to Total Number of Individuals	≤0.13	0.14-0.29	0.30-0.46	0.47-0.68	≥0.69
EPT Count To Chironomid Count	≤0.88	0.89-2.55	2.56-5.70	5.71-11.65	≥11.66
Chironomid Count	≥147	146-55	54-20	19-7	≤6

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Nonimpaired

Habitat Sampling Methods

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to 100. An example of the QHEI data sheet is given in Appendix 7.

Substrate type(s) and quality are important factors of habitat quality and the QHEI score is partially based on these characteristics. Sites that have greater substrate diversity receive higher scores as they can provide greater habitat diversity for benthic organisms. The quality of substrate refers to the embeddedness of the benthic zone. Small particles of soil and organic matter will settle into small pores and crevices in the stream bottom. Many organisms can colonize these microhabitats, but high levels of silt in a streambed can result in the loss of habitat within the substrate, thus sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

Instream cover, another metric of the QHEI, represents the type(s) and quantity of habitat provided within the stream itself. Examples of instream cover include woody logs and debris, aquatic and overhanging vegetation and root wads extending from the stream banks. The channel morphology metric evaluates the stream's physical development with respect to habitat diversity. Pool and riffle development within the stream reach, the channel sinuosity and other factors that represent the stability and direct modification of the site were evaluated to comprise this metric score.

A wooded riparian buffer is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal and assimilation of nutrients. According to the Ohio EPA, (1999), riparian zones govern the quality of goods and services provided by riverine ecosystems. Riparian zone and bank erosion were examined at each site to evaluate the quality of the buffer zone of a stream, the land use within the floodplain that affects inputs to the waterway, and the extent of bank erosion, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian buffer is a zone that is forest, shrub, swamp, or woody old field vegetation. Typically, weedy, herbaceous vegetation does not offer as much infiltration potential as woody components and does not represent an acceptable riparian zone type for the QHEI (EPA, 1989).

The fifth QHEI metric evaluates the quality of pool/glide and riffle/run habitats in the stream. When present, these zones provide diverse habitat structure and in turn can increase habitat quality and availability. The depth of pools within a reach and the stability of riffle substrate are some factors that affect the QHEI score in this metric.

The final QHEI metric evaluates the topographic gradient in a stream reach. This is calculated using topographic data. The score for this metric is based on the premise that both very low and very high elevation gradients have negative effects on habitat quality. The gradient ranges for scoring take into account the varying influence of gradient with stream size. Moderate gradients receive the highest possible score of 10 for this metric.

The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1995).

Macroinvertebrate and Habitat Results

QHEI and mIBI scores for each sampling site are given in Tables 54 and 55. Detailed mIBI results are included in Appendix 8. The mIBI scores ranged from 2 to 6.5. All QHEI scores except Lower Mud Pine Creek (63.5) and Humbert Ditch (60.5) fell below 60, the level conducive to existence of warmwater faunas (Ohio EPA, 1999). Figure 49 shows cross-sections of the stream sampling sites. Nearly all of the sites have relatively steep banks, indicative of stream modification and channelization. Following the tables is a site-by-site description of particular characteristics that contributed to the evaluation results.

TABLE 54. Classification Scores and mIBI Score for each sampling site within the Upper Mud Pine Creek Watershed as sampled June 25-26, 2001.

	Humbert Ditch (1)	Howarth Ditch (2)	Wattles Ditch (3)	Seamons Ditch (4)	Upper Mud Pine Creek (5)	Volz Ditch (6)	Goose Creek (7)	Lower Mud Pine Creek (8)
HBI	0	0	0	0	0	0	0	8
No. Taxa (family)	4	6	8	4	4	4	4	4
% Dominant Taxa	6	6	8	8	6	2	8	6
EPT Index	0	0	2	0	4	0	0	6
EPT Count	0	0	0	0	0	0	0	4
EPT Count/Total Count	2	0	0	0	2	0	0	8
EPT Abun./Chir. Abun.	0	0	2	0	0	2	0	8
Chironomid Count	4	6	8	4	4	8	6	8
mIBI Score	**2.00**	**2.25**	**3.50**	**2.00**	**2.50**	**2.00**	**2.25**	**6.50**

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Nonimpaired

TABLE 55. Benton County QHEI Scores for the Upper Mud Pine Creek Watershed sampling sites as sampled June 25-26, 2001

Site	Substrate Score	Cover Score	Channel Score	Riparian Score	Pool Score	Riffle Score	Gradient Score	Total Score
Maximum Possible Score	20	20	20	10	12	8	10	**100**
Humbert Ditch (1)	9.5	13	10	5	10	5	8	**60.5**
Howarth Ditch (2)	7.5	12	5	3	8	0	6	**41.5**
Wattles Ditch (3)	1	13	4	2.5	0	0	8	**28.5**
Seamons Ditch (4)	5	13	5	3	5	0	8	**39**
Upper Mud Pine Creek (5)	7.5	6	6	5	3	0	10	**37.5**
Volz Ditch (6)	3.5	6	5	2.5	8	0	6	**31**
Goose Creek (7)	6.5	4	6	4	5	3	4	**32.5**
Lower Mud Pine Creek (8)	8.5	20	12	7	7	5	4	**63.5**

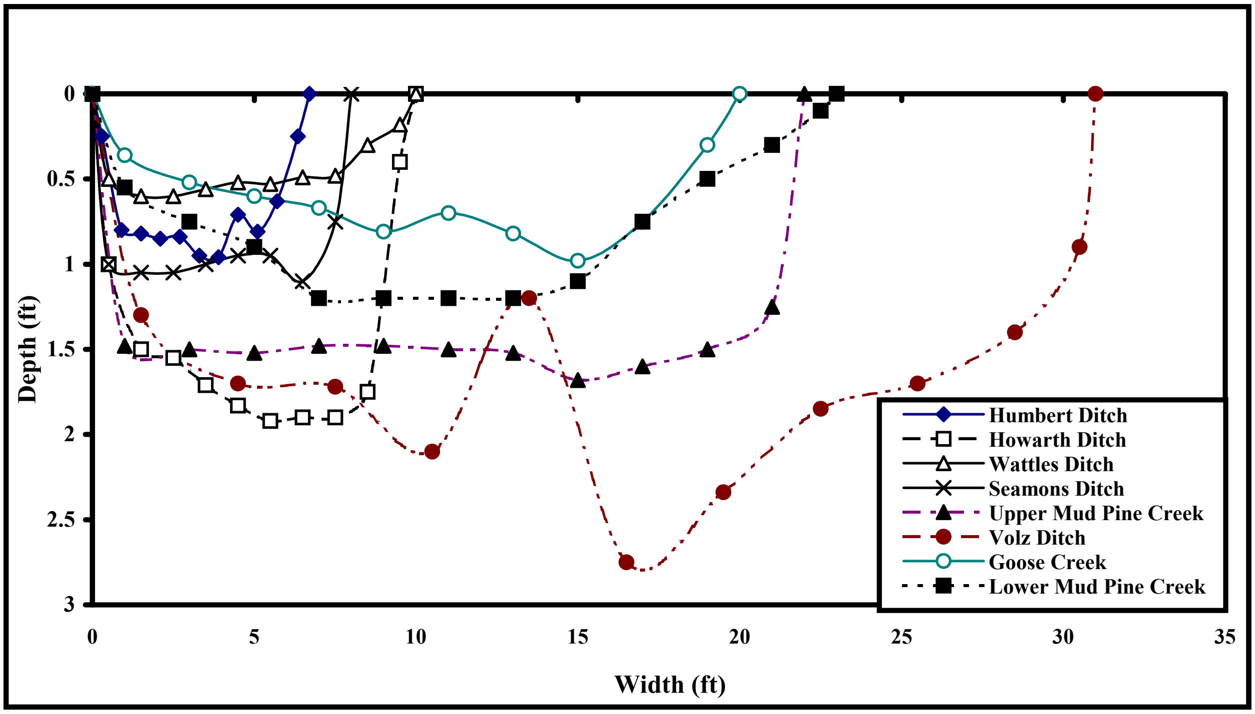

FIGURE 49. Cross-sections of streams at sampling locations.

Site 1 - Humbert Ditch. The QHEI score for Humbert Ditch was 60.5 of 100 possible points. The habitat score was the second highest recorded at any study site. Characteristic features of this site were in-stream cover and riparian vegetation (Figure 50). Trees, shrubs, and grasses dominated the riparian vegetation, providing adequate buffering capacity and enhancing habitat quality. Discrete pool and riffle development also contributed to the score. The substrate at the site was composed of 30% sand, 20% cobble, and smaller percentages of gravel, clay, and boulders. Silt levels in the substrate were normal and embeddedness was low. The mIBI score was the lowest of the study (2.0) indicating a severely to moderately impaired system. Coenagrionidae, a pollution-tolerant family belonging to the Odonata order and dipterans of the Chironomidae family dominated the macroinvertebrate community.

FIGURE 50. Site 1 sampling location on Humbert Ditch.

Site 2 - Howarth Ditch. The Howarth Ditch QHEI score (41.5) indicates relatively poor quality habitat. The riparian zone lacked woody or shrubby vegetation, and overhanging vegetation was sparse (Figure 51). Runoff from adjacent agricultural fields was not impeded by the narrow riparian buffer. The habitat was further limited by a homogenous channel of poor pool quality and lacking riffle development. The stream cross-section (Figure 49) showed that the stream was fairly deep (2 feet) for its relative width (10 feet). The substrate was composed of sand (60%), gravel (25%), boulder, and cobble. The mIBI score (2.3) indicated moderate impairment. The organic pollution-tolerant dragonfly family Coenagrionidae and the gastropod family Physidae were the dominant taxa at this site.

FIGURE 51. Site 2 sampling location on Howarth Ditch.

Site 3 - Wattles Ditch. Wattles Ditch was the shallowest of the study streams, reaching one-half foot at its deepest point (Figure 49). The substrate was predominantly sand with fine particulate organic matter (FPOM), or “muck”. Wattles Ditch lacked any resemblance to a natural waterway in that it was very straight and showed little recovery from channelization (Figure 52). Heavy siltation, extensive embeddedness, and a channel choked with aquatic macrophytes (Figure 52) contributed to the lowest QHEI score (28.5) of any study reach. Riparian vegetation was also lacking, allowing agricultural runoff from adjacent fields to run directly into the stream. Undeveloped pool and riffle sequences and lack of canopy cover also reduced habitat diversity. The mIBI score of 3.5 indicated moderate impairment. Asellidae, a tolerant isopod, and the odonate Coenagrionidae dominated the macroinvertebrate community; lack of community diversity adversely influenced mIBI score.

FIGURE 52. Site 3 sampling location on Wattles Ditch.

Site 4 - Seamons Ditch. Grasses directly bordered Seamons Ditch providing moderate canopy cover (Figure 53). Aquatic macrophyte growth within the channel offered in-stream cover. Even though canopy and in-stream cover were readily available, the QHEI score of 39 indicated that other habitat characteristics were of poor quality. Poor substrate diversity (>50% sand), moderate siltation, and moderate erosion contributed to the low habitat score. A distinct woody riparian area was also lacking. Seamons Ditch received the lowest mIBI score of the study reaches (2.0) indicating moderate to severe impairment. Although a moderate diversity of organisms was collected, a lack of intolerant taxa characterized the macroinvertebrate community.

FIGURE 53. Site 4 sampling location on Seamons Ditch.

Site 5 - Mud Pine Creek. The QHEI score at this site was 37.5 of 100 total possible points. Sand, gravel, and fine silts were the predominant substrates. Shrubs and woody vegetation provided a narrow riparian zone on one bank, while old-field vegetation dominated the other bank (Figure 54). The stream had not recovered from recent channelization, and pool and riffle development was poor. The mIBI score of 2.5 was consistent with the QHEI score indicating a system of moderate degradation. Pollution-tolerant Chironomidae dominated the macroinvertebrate community; the Coenagrionidae and Gastropoda families were also prevalent.

FIGURE 54. Site 5 sampling location on Mud Pine Creek.

Site 6 - Volz Ditch. Heavy siltation and extensive embeddedness characterized the substrate quality and limited habitat diversity at Site 6 on Volz Ditch. Moderate to heavy erosion was observed on both banks of the stream channel. The substrate composition was 50% sand, 20% silt, and 20% gravel. This site was the widest (31 feet) and deepest (2.8 feet) stream reach sampled (Figure 49). Stream depth contributed to the pool quality score, but no riffle development was observed. Volz Ditch lacked a significant riparian zone as the areas adjacent to both sides of the stream were livestock-grazed fields (Figure 55). The QHEI score of 31 was the second lowest of the sites and reflected the relatively poor habitat quality at the site. The low mIBI score (2.0) characterized the impaired macroinvertebrate community. The very tolerant hemipteran family Corixidae dominated the insect sample. Members of the Corixidae taxon breath air and can tolerate low oxygen conditions and high levels of organic pollution. Their prevalence lowered the HBI metric of the mIBI score.

FIGURE 55. Site 6 sampling location on Volz Ditch.

Site 7 - Goose Creek. Heavy siltation and moderate embeddedness characterized the substrate of Goose Creek. The substrate types observed included 40% gravel, 30% sand, and 10% each of boulder, cobble and silt types. The channel was entirely vegetated by a rooted submergent plant species, identified as Eurasian Watermilfoil (*Myriophyllum spicatum*). Woody vegetation created a narrow riparian zone upstream of the double bridge highway sampling location, but woody vegetation was not present in any other section of the sampled stream reach (Figure 56). Although the riparian zone was composed of trees and shrubby vegetation at the sampling site, this zone was very narrow and did not provide adequate buffering capacity from the adjacent agricultural fields and highway. The mIBI score for the site was 2.3 indicating moderate impairment. The very tolerant Corixidae family was the dominant taxa collected.

FIGURE 56. Site 7 sampling location and upstream of sampling location on Goose Creek.

Site 8 - Mud Pine Creek. This site received the highest QHEI score, 63.5 of a possible 100. Substrate composition consisted of 40% cobble, 30% boulder, 20% gravel, and 10% sand; heavy siltation was evident. In-stream cover was extensive resulting in a high score for the cover metric of the QHEI (Figure 57). Channel morphology showed good development and moderate stability. A wide, forested riparian zone bordered the stream, and no stream bank erosion was present. In-stream emergent vegetation was observed in 40% of the reach, providing additional habitat diversity. Riffles and pools were well developed throughout the site. The mIBI score was also the highest of any study site. The score of 6.5 classified the site as nonimpaired. The dominant macroinvertebrates were relatively intolerant taxa; the trichopteran family Hydropsychidae and the ephemeropteran family Oligoneuriidae were the most prevalent macroinvertebrate taxa.

FIGURE 57. Site 8 sampling location on Lower Mud Pine Creek.

Macroinvertebrate and Habitat Discussion

The overall evaluation of biotic health and habitat quality in the Mud Pine Creek Watershed indicates that these waterways are slightly to moderately degraded. Many of the study sites lacked at least one of the key elements of natural healthy stream habitats. These missing key elements limit the ecological functionality of these systems. The QHEI evaluations revealed lack of pool and riffle development. Additionally, QHEI scores pointed out poor substrate quality in watershed streams. These factors are critical for habitat diversity and biological integrity in stream ecosystems. In the Upper Mud Pine Creek Watershed, poor mIBI scores reflected impacted stream habitat quality.

Channel alterations such as ditching, dredging, straightening and other modifications affect stream habitat diversity. Altering the natural stream morphology (shape) impacts riffle and pool development, resulting in few habitat types for macroinvertebrate and fish colonization. Deep pools and shallow riffles can also affect chemical characteristics of flowing water. As reflected in the QHEI evaluations and stream cross-sections, many of the study reaches have been impacted by channelization. Steep stream banks and straight reaches indicate that these streams have been modified and lack natural sinuosity and development.

Another important aspect of good habitat quality that is conspicuously missing from many of the study sites is an effective riparian zone to buffer stream systems from the surrounding land use. Stable, woody vegetation zones that naturally form adjacent to streams and other waterways provide distinct functions that enhance habitat quality (Ohio EPA, 1999). Primarily, this zone slows runoff, collects sediment, and stores nutrients that would otherwise be loaded into the stream system. Poor QHEI and mIBI scores were also related to riparian zone absence. Lower Mud Pine Creek at Site 8 benefited from a healthy riparian zone and also supported a healthy macroinvertebrate community. Extensive woody vegetation around streams provides additional habitat in the forms of logs and woody debris, overhanging vegetation, and submerged root wads. Riparian vegetation provides canopy cover that shades the stream and minimizes thermal inputs. Shade can limit extensive, nuisance levels of aquatic vegetation that are dependent upon sufficient levels of solar radiation. Short grassy vegetation grazed by livestock adjacent to streams does little to slow flows in the stream and therefore is less capable of trapping sediments and nutrients. Based on observations made during sampling events, the quality and quantity of riparian zone vegetation is moderately to severely limited.

Each of these physical factors contributes to habitat quality, and their absence or degradation at most sites is related to the macroinvertebrate community structure. Overall, the mIBI scores were rather low with the exception of Mud Pine Creek at Site 8. Site 8 received the highest QHEI and mIBI scores, suggesting that habitat factors do have an impact on the quality of ecological communities. The other seven sites received mIBI scores indicating varying degrees of "moderate" impairment. In a healthy stream system, a community of both tolerant and intolerant taxa is expected. Impacts of degradation will tend to limit or eliminate organisms that are incapable of persisting in such systems. In general, tolerant taxa dominated samples, leading to lower mIBI scores. Site 8 was the only site to score above a zero for the HBI metric, which directly rates community tolerance.

It is important to remember that overall watershed condition will impact habitat and biotic quality. In fact, scientific data suggest that watershed condition may have a greater influence on macroinvertebrate metrics than local riparian land use (Weigel et al., 2000). So although local streamside best management practices are important, a broader, watershed-level approach is necessary to effectively address biotic integrity and stream health. For example, Humbert Ditch (Site 1) received a QHEI score of greater than 60, but water quality as assessed using the macroinvertebrate community was classified on the low end of moderately impaired (2.0). An additional study by Osmond and Gale (1995) showed that large-scale reductions in agricultural non-point source pollution are necessary for stream health and improvement. Examples of working at a watershed level include coordinating with producers to implement nutrient, pesticide, tillage and coordinated resource management plans.

Macroinvertebrate and Habitat Summary

Because many of the stream reaches surveyed had been channelized in the past, many stream characteristics were absent or severely deficient as indicated by the low QHEI scores. The overall habitat degradation components that impair conditions for aquatic life within the Mud Pine Creek Watershed were:

- Poor pool-riffle development: deep places (pools) and shallow places (riffles) within a stream reach offer habitat variety for aquatic organisms and can impact certain chemical characteristics of flowing water like temperature, dissolved oxygen concentrations, and suspended sediment load.
- Siltation/substrate embeddedness: excessive loading of fine sediments and silt clogs or embeds the substrate spaces destroying habitat for aquatic invertebrates and fish.
- Channel alterations: ditching, dredging, straightening, and other changes to channel structure can affect the ability of organisms to live in the stream.
- Poor in-stream cover: in-stream cover like undercut banks, overhanging vegetation, woody debris, and aquatic vegetation offer protection and habitat for aquatic organisms. Like pools and riffles, in-stream cover also is related to certain chemical characteristics like temperature and dissolved oxygen.
- Lack of or very narrow riparian zone: farming and other land use practices very near or even at the stream's edge decrease canopy cover over the stream allowing for increased thermal pollution inputs to the stream. Additionally, narrow riparian areas do not filter or infiltrate runoff as efficiently as filter areas that are at least 30 feet wide (NRCS, 2000).

These habitat characteristics are important for the aquatic life which inhabits streams. As one would expect, the impaired habitat conditions in the study streams were reflected in mIBI scores. In general, sites with poorer habitat fostered poorer macroinvertebrate communities of higher pollution tolerance and lower diversity. Only two of eight QHEI scores exceeded the level of 60 that has been found to be conducive to aquatic life, and mIBI scores ranged from "severely" impaired to "slightly" impaired.

Relationships Among Chemical, Biological, and Habitat Characteristics

Chemical parameters and biological and habitat indices were analyzed for relationships that could provide additional insight into mechanisms governing impairment within the subwatersheds. The following list includes parameters for which no statistically significant linear relationship was found:

- QHEI Score vs. mIBI
- QHEI Score vs. Flow (cfs)
- QHEI Score vs. Turbidity (NTU)
- QHEI Score vs. TSS (mg/l)
- mIBI vs. DO (mg/l)
- mIBI vs. NO_3^- (mg/l)
- mIBI vs. TKN (mg/l)
- mIBI vs. TP (mg/l)
- QHEI Substrate vs. mIBI
- QHEI Pool vs. mIBI
- QHEI Riffle vs. mIBI

One explanation for this lack of correlation is that these creeks are, in general, highly modified, somewhat artificial drainage ditches, and consequently might not reflect natural relationships among parameters of water quality, habitat quality, and biological health. In many cases, the response variable showed such a limited range (due to being highly modified) that correlation was impossible.

Three positive correlations were found among physical and habitat parameters:

- QHEI vs. HBI (Figure 58)
- mIBI vs. Flow (cfs) (Figure 59)
- mIBI vs. QHEI Cover (Figure 60)

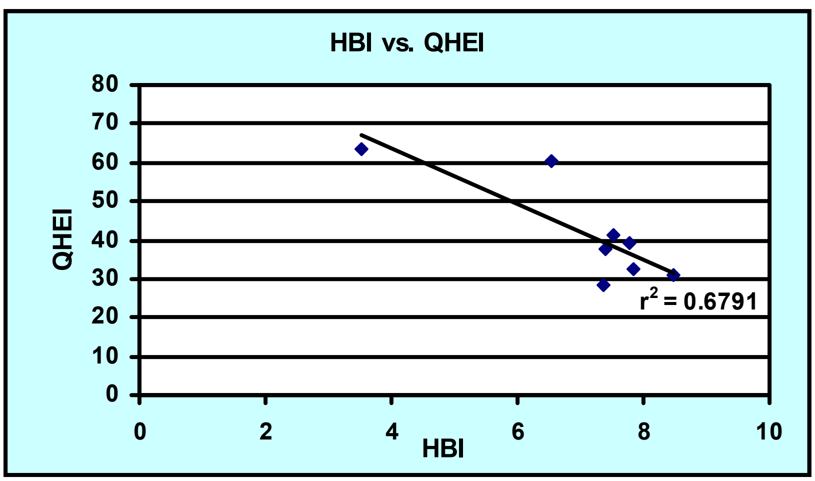

FIGURE 58. Statistically significant relationship (p=0.012) between the family-level HBI and QHEI scores measured for the Upper Mud Pine Creek Watershed streams.

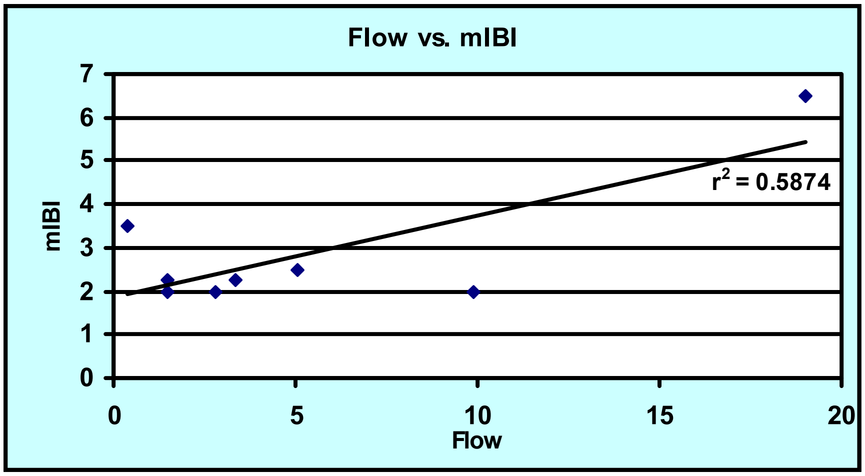

FIGURE 59. Statistically significant relationship (p=0.27) between discharge and mIBI scores measured for the Upper Mud Pine Creek Watershed streams.

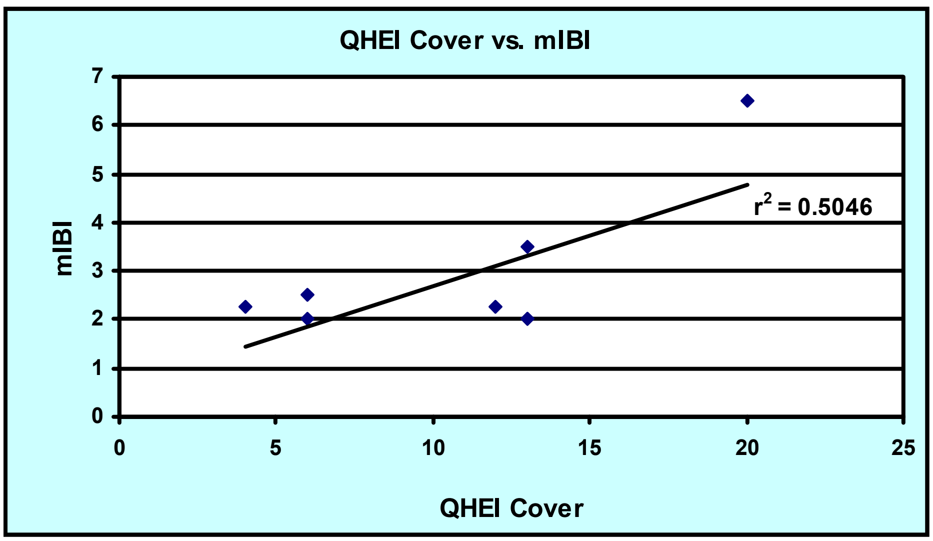

FIGURE 60. Statistically significant relationship (p=0.048) between QHEI Cover parameter and mIBI measured for the Upper Mud Pine Creek Watershed streams.

The HBI and QHEI were inversely related, indicating that a lower QHEI score corresponded to a more tolerant macroinvertebrate community (Figure 58). Based on this data, it is reasonable to expect improvements in biotic health (as measured by organism tolerance to pollution) if habitat restoration projects are undertaken.

The relationship illustrated between discharge and mIBI (Figure 59) is expected based on the importance of flow and stream dynamics. Flowing water brings a continuous supply of nutrients and food particles to stream biota, not to mention increased dissolved oxygen. For example, the concentrations of dissolved organic matter (DOM) increase as a function of discharge in many streams (Allan 1995). The concentration of particulate organic matter (POM) increases with the first flush of a storm event and then becomes diluted with additional discharge as the supply of POM is exhausted. In systems like Mud Pine Creek, where there is an overabundance of organic matter present in the stream and its substrate, higher discharges can mobilize and transport the POM. As Hynes (1970) stated in his classic work, current makes the water "physiologically richer" because of its constant renewal of materials in solution near the surfaces of stream organisms.

The relationship illustrated in Figure 60 is based on the premise that greater habitat availability as "cover" positively influences the macroinvertebrate community that inhabits these spaces. Additionally, rootwads, aquatic vegetation, and large woody debris represent sources of organic matter that when retained in the stream can be utilized as habitat and/or food resources. Other objects like boulders can also provide cover and can serve as a trap for course and fine particulate organic matter (CPOM and FPOM).

PHOSPHORUS MODELING

Since phosphorus is the limiting nutrient in most lakes and reservoirs, watershed management programs often target phosphorus as a nutrient to control. Because of this, we have used a phosphorus model to estimate the dynamics of this important nutrient in these watersheds.

The limited scope of this LARE study did not allow us to determine phosphorus inputs and outputs outright. Therefore, we have used a standard phosphorus model to estimate the phosphorus budget. Reckhow et al. (1980) compiled phosphorus loss rates from various land use activities as determined by a number of different studies and calculated phosphorus export coefficients for each land use in the watershed. We used mid-range estimates of these phosphorus export coefficient values for most watershed land uses (Table 56). Because of the relatively high use of conservation tillage practices in Benton County, we lowered the expected phosphorus export coefficient from row crop agriculture from 2.0 kg/ha yr to 1.4 kg/ha yr in our model.

TABLE 56. Phosphorus Export Coefficients (units are kg/hectare-yr except the septic category, which are kg/capita-yr).

Estimate Range	Row Crops	Non-Row	Pasture	Forest	Precip.	Urban	Septic
High	5.0	1.5	2.5	0.3	0.6	3.0	1.8
Mid	2.0	0.8	0.9	0.2	0.3	1.0	0.4-0.9
Low	1.0	0.5	0.1	0.1	0.15	0.5	0.3

Source: Reckhow et al. (1980)

Phosphorus export coefficients are expressed as kilograms of phosphorus lost per hectare of land per year. These are multiplied by the amounts of land in each of the land use category to derive an estimate of annual phosphorus export (as kg/year) for each land use per watershed (Table 57).

Because row crop agriculture is the dominant land use within each of the subwatersheds, the proportional mass of phosphorus estimated from row cropland is also high – over 91% of the total estimated phosphorus loss. The percentage phosphorus loss due to row crops ranges from a low of 89% in the Lower Mud Pine Creek (8) Subwatershed to a high of 96% in the Howarth Ditch (2) Subwatershed. When the data have been normalized for subwatershed area (Table 58), all sub-basins contribute almost even amounts of phosphorus. According to the model, the Howarth Ditch Subwatershed loaded the most phosphorus per unit area. The model estimates that 22,529 kilograms (24.8 tons) of phosphorus is lost from lands within the project area each year. Significant reduction of phosphorus loading to local streams will necessitate additional management of agricultural sources.

TABLE 57. Results of phosphorus export modeling by subwatershed given in kg/yr.

	P-Export Coefficient[a]	Humbert (1)[b]	Howarth (2)	Wattles (3)	Seamons (4)	Upper MPC (5)	Volz (6)	Goose (7)	Lower MPC (8)	TOTALS	% of Total
Deciduous Forest	0.2	2.9	1.4	0.8	2.9	1.3	3.2	4.3	11.2	28.1	0.0012
Emergent Herbaceous Wetland	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.6	0.0000
Evergreen Forest	0.15	0.0	0.0	0.0	0.0	0.0	0.3	0.1	1.2	1.9	0.0001
Grassland	0.6	8.4	3.2	0.2	6.3	0.9	5.3	12.0	12.2	48.5	0.0022
High Intensity Residential	1.9	0.0	0.0	0.0	0.0	0.2	0.0	22.9	0.0	71.5	0.0032
High Intensity Commercial/Ind	1.5	36.8	9.2	0.0	0.0	0.0	9.5	37.1	35.9	128.5	0.0057
Low Intensity Residential	1	48.7	1.9	0.3	0.0	0.0	0.0	33.5	5.0	89.4	0.0040
Open Water	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0000
Other Grasses (Parks)	0.6	11.1	0.6	0.0	0.0	0.0	0.0	0.2	1.3	13.3	0.0006
Pasture Hay	0.9	179.6	68.7	61.3	124.2	92.0	214.8	320.0	406.9	1467.5	0.0651
Row Crops	1.4	2846.5	1818.6	633.0	1862.1	1558.3	3646.1	4422.9	3892.3	20679.8	0.9179
Small Grains	0.7	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.2	0.0000
Woody Wetlands	0.1	0.3	0.1	0.0	0.5	0.0	0.4	0.4	2.4	4.1	0.0002
TOTAL		**3134.0**	**1903.7**	**695.7**	**1995.5**	**1652.8**	**3879.2**	**4853.0**	**4366.3**	**22529.0**	**1.0**

[a]From Reckhow et al. (1980)
[b]All units are kilograms phosphorus per year

TABLE 58. Results of phosphorus export modeling by subwatershed given in kg/ha-yr.

Subwatershed	Phosphorus Export (kg/ha-yr)
Humbert Ditch (1)	0.53
Howarth Ditch (2)	0.55
Wattles Ditch (3)	0.54
Seamons Ditch (4)	0.54
Upper Mud Creek (5)	0.55
Volz Ditch (6)	0.55
Goose Creek (7)	0.54
Dry Run (9)	0.52

RECOMMENDATIONS

All of the smaller watersheds within the Upper Mud Pine Creek Watershed could benefit from land treatment and best management strategies as already described in detail in the Watershed Investigation Section. Finances, time, manpower, and other restraints make it impossible to implement all of these management techniques at once. Thus, it is necessary to prioritize the recommendations.

These prioritizations and recommendations are simply guidelines based on conditions documented during this study. These conditions may change as land use within the watershed changes. Management efforts may need to be prioritized differently based on project feasibility and individual landowner willingness to participate. To ensure maximum participation in any management effort, all watershed stakeholders should be allowed to participate in prioritizing the management efforts in the watershed.

It is also important to note that even if all stakeholders agree that this is the best prioritization to meet their needs, action need not be taken in this order. Some of the smaller, less expensive recommendations may be implemented while funds are raised to implement some of the larger projects. Many of the larger projects will require feasibility work to ensure landowner willingness to participate in the project. In some cases, it may be necessary to attain regulatory approval as well. Landowner endorsement and regulatory approval along with stakeholder input may ultimately determine the prioritization of management efforts.

Results from the mapping exercises, the aerial tour, the windshield survey, water quality sampling, biological sampling, habitat sampling, and the modeling exercise were used to prioritize subwatersheds for future work. An additional issue recognized during prioritization was scheduled ditch maintenance projects. As already discussed in the Watershed Investigation Section, Howarth and Volz Ditches are scheduled for maintenance within the near future.

In the following section, the subwatersheds are discussed in order of priority. It is also important to note that in order to make prioritizations, it is necessary to make some generalizations. Additional general recommendations, like innovative riparian management system use and recommended practices for homeowners, follow the primary recommendations section. Many of these recommendations may already be in practice; however, for the sake of thoroughness, they are reiterated here.

Prioritization

Based on the findings of this study, the order of prioritization for work, projects, and program enrollment within the Upper Mud Pine Creek Watershed should be:

1. Goose Creek Subwatershed
2. Seamons Ditch Subwatershed
3. Upper Mud Pine Creek Subwatershed
4. Humbert Ditch Subwatershed
5. Wattles Ditch Subwatershed
6. Lower Mud Pine Creek Subwatershed
7. Volz Ditch Subwatershed

8. Howarth Ditch Subwatershed

Goose Creek (7) is of top priority due to high pollutant loading rates for suspended solids, total phosphorus, and *E. coli*. The Goose Creek subbasin area also contains relatively more highly erodible land than surrounding drainages. The mIBI indicated a "moderately" impaired system, and the drainage loaded disproportionate amounts of sediment and nutrient parameters relative to flow rate. Twenty-two potential project sites where grassed waterways, filter strips, and wetland restoration could be implemented were located during aerial and windshield tours of its drainage.

Seamons Ditch (4) is also of high priority due to relatively large amounts of unprotected highly erodible land in its drainage and due to receiving the lowest mIBI score of any study reach (2.0). This score classifies water quality in Seamons Ditch as "moderately to severely" impaired.

Upper Mud Pine Creek (5) discharged more *E. coli* than any other study subwatershed during base flows and almost as much bacteria as Goose Creek during storm flows. The phosphorus-loading model estimated annual nutrient loading to be the highest for this drainage. Fourteen potential conservation projects were noted in the Upper Mud Pine Creek Subwatershed. Some of these projects included filter strips and grassed waterways.

Humbert Ditch (1) is also listed as a priority subwatershed. During both base and storm flows, Humbert Ditch loaded disproportionate amounts of dissolved and particulate phosphorus relative to flow rate. The mIBI indicated "moderate" to "severe" impairment of water quality within the ditch. Among other projects, one site for potential wetland restoration was noted in this subbasin. Wetland restoration in the headwaters of Mud Pine Creek could have positive ramifications for the watershed as a whole.

The remaining four subwatersheds are of lower priority because they were generally responsible for lower amounts of pollutant loading and/or generally already contain more protected land in CRP relative to HEL than the subwatersheds of top priority. However, projects and landowner participation in these areas should not be discouraged. As will be discussed in the Funding Sources and Watershed Resources Section, the primary obstacle facing watershed projects is typically landowner willingness to participate (Osmond and Gale, 1995). Management and participation certainly should be encouraged in the remaining four subwatersheds of lower overall priority, while keeping in mind that Howarth and Volz Ditches are scheduled for maintenance (dredging) projects. Best Management Practice (BMP) treatment of Howarth and Volz Ditches should be strongly encouraged and pursued immediately following ditch maintenance project completion.

Primary Recommendations

1. Apply for Lake and River Enhancement (LARE) Watershed Land Treatment Funds to implement recommended BMPs and projects discussed for each subwatershed (Tables 34-42) based on subwatershed priority. Some of these projects included: wetland restoration, filter strip installation, allowing for natural riparian vegetation growth, bank stabilization, livestock fencing, information and education efforts, buffer zone establishment, revegetation of exposed areas, and grassed waterway construction. This work should focus on interested landowners in identified critical areas first. Additionally,

Mr. Leuck with the town of Fowler indicated during the study that the town would be willing to work with the SWCD to install additional stormwater detention basins to retain and treat surface runoff from the town area.

2. Coordinate the projects referenced in recommendation #1 with the county drainage board to ensure that the project meets goals of both the Soil and Water Conservation District (SWCD) and the drainage board. For example, a SWCD tree-planting project in an area that is scheduled for drainage project de-brushing will not result in the optimum use of resources. In fact, a landowner may be more willing to participate in a cost-share program following ditch maintenance projects. As already mentioned, Howarth and Volz Ditches will be cleaned within the near future. Following the maintenance projects, these ditches and their immediate watersheds should be thoroughly treated with conservation practices to prevent the need for such projects in the future. It is recommended that the SWCD work closely with the drainage boards to ensure that conservation practices advocated in the Indiana Drainage Handbook (Burke, 1996) are followed when planning and implementing projects. These conservation practices recommend tree preservation, vegetative stabilization and seeding, stream environment enhancement, and tree replacement even near regulated drains. Additionally, the Indiana Lakes Management Work Group, an Indiana Legislature authorized and governor appointed group, also recommended that "drainage boards…implement all possible best management practices as indicated in the Indiana Drainage Handbook" (Case and Seng, 1999). The Group further suggested that the 1965 Indiana Drainage code (IC 36-9-27) be updated to "allow ditch maintenance assessments to be used to cost-share preventative measures such as streambank stabilization, riparian vegetation, and stable livestock access and stream crossings" and to "require drainage boards to develop a master plan (based on sound watershed management practices and with input from landowners) for each drain that proactively identifies sections of stream where landowners can restore protective riparian vegetation along stream sections that are never accessed for drain maintenance".
3. Extend management to the watershed-level. Although streamside localized BMPs are important, research conducted in Wisconsin shows that the biotic community mostly responds to large-scale watershed influences rather than local riparian land use changes (Weigel et al., 2000). Examples of working at the watershed-level include coordinating with producers to implement nutrient, pesticide, tillage, and coordinated resource management plans. It is important to note that the LARE Program will provide cost-share incentives for large-scale land practices like conservation tillage. Large-scale reductions in agricultural non-point source pollutions are necessary for stream health improvement (Osmond and Gale, 1995).
4. Provide information about streams within the Upper Mud Pine Creek Watershed to local landowners. Landowners will be more likely to conserve and protect the creeks if they understand their value. The outreach program could include pointers on how landowners themselves can help protect the waterways.

General Recommendations

1. Develop a watershed or land use management plan. A watershed management plan documents current conditions within a watershed, sets forth goals for the watershed based on stakeholders' desires, forwards a plan of how to reach the goal, and provides for monitoring of success toward reaching the goal. To be effective, all stakeholders must be

included in the plan's development. Much of the information included in the current study could be used to develop this plan; IDEM's Watershed Management Plan requirements may be obtained from Matt Jarvis with the NRCS at (765) 564-4480.

2. Before initiating watershed treatment projects, consider conducting a survey of landowners in the watershed to determine landowners' concern for water quality problems, to evaluate landowners' opinions of management systems, and to quantify the value of surface and groundwater quality improvement. Use this information to work with interested landowners to formulate individual Resource Management Plans.
3. Reach out to a school or other volunteer group to set up volunteer monitoring within the watershed through the Hoosier Riverwatch Program. This data will be a valuable resource by which to evaluate the success of projects implemented in the area.
4. Consider using innovative riparian management systems similar to the one discussed earlier in the Best Management Practice Section. Modified systems of this type would be especially beneficial for use in critical or vulnerable stream reaches where they could significantly impact non-point source pollution. Several critical stream reaches were identified by this study.
5. Invite producers and other landowners out to successful project sites. There is no better advertisement than a success story. Focus on information dissemination and transfer by scheduling on-site field days during non-busy seasons.
6. Work with a bulk seed distributor to make native plant seed available in large quantities at low prices.
7. Work with the Benton County Health Department to ensure proper siting and engineering of septic systems. The use of alternative technology should be encouraged when conditions may compromise proper waste treatment. IDNR and USDA soil scientists in the area are a valuable resource for expertise in characterizing soils for septic use. Their knowledge could be tapped for future building and siting of systems. If building was necessary on a site where conditions were not suitable for a traditional system, alternative technology could be constructed and the site used as a demonstration and education/outreach tool.
8. Homeowners in the watershed should:
    a) Avoid lawn fertilizing near the stream's edge.
    b) Examine all drains that lead from roads, driveways, or rooftops to the stream, and consider alternate routes for these drains that would filter pollutants before they reach the water.
    c) Keep organic debris like lawn clippings, leaves, and animal waste out of the water.
    d) Avoid mowing up to the stream's edge; allow natural riparian vegetation growth.
    e) Properly maintain on-site wastewater treatment systems. Systems should be pumped regularly and leach fields should be properly cared for. Undue pressure on systems may be alleviated by water conservation practices as well.
    f) Maintain field drainage tiles and use filter strips around tile risers.
    g) Consider working with the Benton County NRCS to formulate a Resource Management Plan for each individual property.

ADDITIONAL FUNDING SOURCES AND WATERSHED RESOURCES

Funding and other resources are important for the actual implementation of recommended management practices in a watershed. Several cost share and grant programs are available to help offset costs of watershed projects. Additionally, both human and material resources may be available in the watershed.

Funding Sources

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Soil and Water Conservation Districts (SWCDs) can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, those groups interested in improving water quality through the use of grants must become active soon. Once a group is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to SWCDs for watershed management.

Lake and River Enhancement Program (LARE)

This is the program that funded this diagnostic study. LARE is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a specific project or $300,000 for all projects on a specific lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project. LARE also has a "watershed land treatment" component that can provide grants to SWCDs for multi-year projects. The funds are available on a cost-sharing basis with landowners who implement various BMPs. The watershed land treatment program is highly recommended as a project funding source for the Upper Mud Pine Creek Watershed.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must be listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement.

Section 104(b)(3) NPDES Related State Program Grants
Section 104(b)(3) of the Clean Water Act gives authority to a grant program called the National Pollutant Discharge Elimination System (NPDES) Related State Program Grants. These grants provide money for developing, implementing, and demonstrating new concepts or requirements that will improve the effectiveness of the NPDES permit program that regulates point source discharges of water pollution. Projects that qualify for Section 104(b)(3) grants involve water pollution sources and activities regulated by the NPDES program. The awarded amount can vary by project and there is a required 5% match.

Section 205(j) Water Quality Management Planning Grants
Funds allocated by Section 205(j) of the Clean Water Act are granted for water quality management planning and design. Grants are given to municipal governments, county governments, regional planning commissions, and other public organizations for researching point and non-point source pollution problems and developing plans to deal with the problems. According to the IDEM Office of Water Quality website: "The Section 205(j) program provides for projects that gather and map information on non-point and point source water pollution, develop recommendations for increasing the involvement of environmental and civic organizations in watershed planning and implementation activities, and implement watershed management plans. No match is required. For more information on the 310, 104(b)(3), and 205(j) grants, please see the IDEM website
http://www.in.gov/idem/water/planbr/wsm/Section205j_main.html.

Other Federal Grant Programs
The USDA and EPA award research and project initiation grants through the US National Research Initiative Competitive Grants Program and the Agriculture in Concert with the Environment Program.

Watershed Protection and Flood Prevention Program
The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture (USDA) and is administered by the Natural Resources Conservation Service (NRCS). Funding targets a variety of watershed activities including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program
As already discussed, the Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency (FSA). CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good wildlife habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Currently the program offers continuous sign-up for practices like grassed waterways and filter strips. Participants in the program receive

cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the NRCS. WRP is a subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

North American Wetland Conservation Act Grant Program

The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish and other wildlife. The match for this program is on a 1:1 basis.

Wildlife Habitat Incentive Program

The Wildlife Incentive Program (WHIP) is funded by the USDA and administered by the NRCS. This program provides support to landowners to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary program designed to provide assistance to producers to establish conservation practices in target areas where significant natural resource concerns exist. Eligible land includes cropland, rangeland, pasture, and forestland, and preference is given to applications which propose BMP installation that benefits wildlife. EQIP offers cost share and technical assistance on tracts that are not eligible for continuous CRP enrollment. Certain BMPs receive up to 75% cost share. In return, the producer agrees to withhold the land from production for five years. Practices that typically benefit wildlife include: grassed waterways, grass filter strips, conservation cover, tree planting, pasture and hay planting, and field borders. Best fertilizer and pesticide management practices are also eligible for EQIP cost-share.

Forestry Incentives Program

The NRCS Forestry Incentives Program (FIP) provides cost share dollars for forestry conservation activities like tree planting and timber stand improvements on privately-owned forest land. The program will share up to 65% of the cost of these and other related practices up to $10,000 per landowner per year. To be eligible for FIP, a particular parcel of land must be: smaller than 1,000 acres, be privately owned and non-industrial, be suitable for land management practices like aforestation, reforestation, or stand improvements, and be of sufficient productivity to yield marketable crops.

Farmland Protection Program

The Farmland Protection Program (FPP) provides funds to help purchase development rights in order to keep productive farmland in use. The goals of FPP are: to protect valuable, prime farmland from unruly urbanization and development; to preserve farmland for future generations; to support a way of life for rural communities; and to protect farmland for long-term food security.

Debt for Nature

Debt for Nature is a voluntary program that allows certain FSA borrowers to enter into 10-year, 30-year, or 50-year contracts to cancel a portion of their FSA debts in exchange for devoting eligible acreage to conservation, recreation, or wildlife practices. Eligible acreage includes: wetlands, highly erodible lands, streams and their riparian areas, endangered species, or significant wildlife habitat, land in 100-year floodplains, areas of high water quality or scenic value, aquifer recharge zones, areas containing soil not suited for cultivation, and areas adjacent or within administered conservation areas.

Non-Profit Conservation Advocacy Group Grants

Various non-profit conservation advocacy groups provide funding for projects and land purchases that involve resource conservation. Ducks Unlimited and Pheasants Forever are two such organizations that dedicate millions of dollars per year to projects that promote and/or create wildlife habitat. According to Bob Porch, the IDNR wildlife biologist at Willow Slough, Pheasants Forever does not currently have a Benton County Chapter, but the Lafayette Chapter is somewhat active in the Mud Pine Creek Watershed area.

Watershed Resources

An important but often overlooked factor in accomplishing goals and completing projects in any watershed is resources within the watershed itself. These resources may be people giving of their time, local schools participating in projects, companies giving materials for project construction, or other donations. This section documents some of these available resources for the Upper Mud Pine Creek Watershed. It is important to note that this list is not all-inclusive, and some groups and donors may have been missed.

Watershed Coordinator

The Indiana Department of Environmental Management (IDEM) and the USDA cosponsor three regional watershed conservationist positions. The watershed conservationist is an advocate for watershed-level work in the region. Watershed conservationists can help direct actions of groups and stakeholders who are interested in working together to address problems in their watershed. They can help with everything from structuring public meetings to assisting with the compilation of a Watershed Management Plan. Their wealth of knowledge includes ideas about how to work with and respect all stakeholders in order to find the best plan for natural resource conservation within your watershed. Matt Jarvis is the regional watershed conservationist for the northern third of Indiana and has an office in the NRCS office in Delphi, Indiana. His contact information is found below.

Matt Jarvis
Regional Watershed Conservationist
Natural Resources Conservation Service
1523 N. US Highway 421, Suite 2
Delphi, Indiana 46923-9396
(765) 564-4480
matt.jarvis@in.usda.gov

Coordinated Resource Management

The Coordinated Resource Management (CRM) process is an organized approach to identification of local concerns, evaluation of natural resources, development of alternative actions, assistance from technical specialists, implementation of a selected alternative, evaluation of implementation activities, and involvement of all interested parties who wish to participate in watershed action. The goal is an effective Watershed Management Plan through the establishment of common goals and actions to achieve those goals. Further CRM information and its complementary Watershed Action Guide can be downloaded from the USDA/NRCS website at http://www.in.nrcs.gov. The CRM gives guidance on how to plan with people to maximize benefits to the greatest number of people while enhancing or maintaining the natural resource.

Hoosier Riverwatch

The Hoosier Riverwatch Program was started in 1994 by the State of Indiana to increase public awareness of water quality issues and concerns. Riverwatch is a volunteer stream monitoring program sponsored by the IDNR Division of Soil Conservation in cooperation with Purdue University Agronomy Department. Any citizen interested in water quality may volunteer to take a short training session held from May through October. Water monitoring equipment may be supplied to nonprofit organizations, schools, or government agencies by an equipment grant. Additionally, many SWCD offices (including the Benton County SWCD) have loaner equipment that can be borrowed. A school group at Fowler Elementary in Benton County also received an equipment grant from the Riverwatch Program. Table 56 contains information about groups that have conducted volunteer monitoring within the Middle Wabash-Little Vermillion Watershed. Because Mud Pine Creek has never been monitored through the Hoosier Riverwatch Program, more participation should be advocated within the study watershed especially since loaner equipment is readily available. More detailed information is available via the Hoosier Riverwatch web site at http://www.state.in.us/dnr/soilcons/riverwatch/.

TABLE 56. Groups that have participated in the Hoosier Riverwatch volunteer monitoring program in the Middle Wabash-Little Vermillion Watershed, the 8-digit watershed to which the Upper Mud Pine Creek belongs.

County	Organization/Individual	Stream/Waterbody
Fountain	Attica School Corporation	Little Shawnee Creek
Fountain	Fountain SWCD	Granam Creek
Vigo	Vigo SWCD	Wabash River
Pulaski	Doug Winslow	Indian Creek

Indiana Department of Natural Resources

Bob Porch, the wildlife biologist at Willow Slough in Newton County, could offer assistance and management recommendations as conservation projects are built in the area especially if landowners have an interest in managing the property for wildlife. Bob has worked to provide several IDNR gamebird habitat areas in the study watershed as well as in the adjacent Pine Creek Watershed. Mr. Porch can be contacted at: 5047 W 600 S, Morocco, Indiana 47963, (219) 285-2704.

Volunteer Groups

Volunteer groups can be instrumental in planning projects, implementing projects, and monitoring projects once they are installed. Although no streams in the study watershed have been monitored by Hoosier Riverwatch participants, the Fowler Elementary School has been granted equipment and should be encouraged to participate in the program. The school is located in Fowler and may even be in the Mud Pine Creek Watershed. Involving the people living in the watershed, especially school-age children, is a good way to promote natural resource awareness and a good way to get data collected and projects completed. Oftentimes, data collected by volunteer groups may be the only available data for a watershed. This data is very valuable in helping to establish baseline trends with which to compare future samples.

Conservation Groups

According to Bob Porch, the IDNR wildlife biologist at Willow Slough, the Lafayette Chapter of Pheasants Forever has been involved in purchasing property for wildlife habitat and conservation in the Pine Creek area. Roger McClellan is the contact for the organization and can be reached at: 4618 E 50 N, Lafayette, Indiana 47905, Home: (765)488-6431, Work: (765) 4223-1505 ext.210.

The EPA lists two other volunteer organizations active in Indiana that may have an interest in protecting water quality in the Mud Pine Creek area. The Friends of Sugar Creek, Inc. based out of Darlington, Indiana is a conservation organization which conducts quarterly monitoring of Sugar Creek and organizes community outreach and education regarding water quality in Sugar Creek. Sugar Creek flows through Turkey Run State Park before converging with the Wabash River downstream of Big Pine Creek. Mud Pine Creek and Sugar Creek are located within the same 8-digit watershed. More information about Friends of Sugar Creek is available from their coordinator Sean Grady who can be reached at 9765) 362-5351. Additionally, Wildcat Guardians, Inc. in Kokomo, Indiana is actively involved in water quality issues that pertain to Wildcat Creek, which is also a tributary to the Wabash River. Wildcat Guardians are involved in monitoring programs and information dissemination. More information about the Wildcat Creek organization may be found online at http://www.indianaoutfitters.com/WildcatGuardians.

Purdue University Groups

A Purdue University professor Barry Dunning has been fairly active in academic study of the restored wetlands in the Pine Creek area. Dr. Dunning is with the Department of Forestry and Natural Resources and is primarily interested in shorebird management in wetland areas. He may be a knowledgeable resource if wetland restoration is considered in the Mud Pine Creek Watershed. Dr. Dunning can be contacted at: Purdue University School of Agriculture, Department of Forestry and Natural Resources, West Lafayette, Indiana 47907-1159, (765) 494-3565.

Purdue Agricultural Center (PAC) Research and Demonstration Projects

The Throckmorton-Purdue Agricultural Center (TPAC) in Lafayette participates in on-going agricultural research that is relevant to challenges producers face in northern Indiana. Researchers are currently conducting a wide variety of studies that have direct implications for better farming practices in the study watershed. A few of these projects include: 1) evaluation of new insecticides to control crop pests like corn rootworm; 2) generation of data for extension recommendations; 3) testing of new potassium soil testing techniques for improved ability to predict soil potassium supply; 4) evaluation of cover crop effect on soil structure and nutrient conservation and availability under no-till and conventional tillage systems; 5) investigating the effects of filter strips on crop production via alterations in the community dynamics of arthropods, small mammals, and birds; 6) determination of the effects that different crop rotations in tilled and no-till plots have on soil characteristics and erosion; 7) researching seed priming of prairie grasses to make their use more feasible for rapid establishment, erosion prevention, and general landscape use; 8) finding windbreak and filter strip planting designs with income potential; 9) developing an understanding of the interactions between crop pests and their natural predators. This research may provide insight on future management techniques that could be applicable to the Mud Pine Creek area. Additionally, the TPAC is home to a wetlands mitigation project that provides students, wildlife biologists, and preservation groups the opportunity for study and observation. An experimental septic system at the site also provides a training opportunity for septic installers and county sanitarians on how to lessen man's affect on rural watersheds.

Obstacles for Watershed Projects

Although the current study did not directly identify obstacles or special challenges for watershed-level projects in the Upper Mud Pine Creek Watershed, data collected during a phone survey of hundreds of producers in the 21 Rural Clean Water Program (RCWP) project areas provides some information with respect to the most typical obstacle encountered in watershed projects: private landowner willingness to participate. The purpose of the survey was to evaluate difference between farmers who chose to participate in the RCWP projects and those who did not (Gale et al., 1993). Participation was positively correlated with the following factors: total acreage farmed, farm sales, property/equipment values, water pollution awareness, access to water quality/conservation materials and information, education level, willingness to take risks, availability of financial (cost-share) incentives, and level/frequency of one-to-one contact between project personnel and farmers (Osmond and Gale, 1995). (An example of a positive correlation would be that more producers participated if more cost-share incentives were available.) The study found that producers who were tenant farmers or were employed off-farm were less likely to participate in conservation programs. The main reason landowners did not participate was that they did not believe water quality to be a problem.

The Benton County SWCD can take action to overcome this obstacle of private landowner willingness to participate. The primary recommended action is discussed in recommendation #4: providing landowners with information about water quality and the various programs (like LARE) that are available to cost-share best management initiatives. The SWCD may be able to use the LARE watershed land treatment project as a “showcase” project to build stakeholder interest and participation. The District could also encourage a local high school science class to initiate volunteer monitoring in the watershed in order to raise awareness and provide education for children.

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APPENDICES

APPENDIX 1:

Detailed Land Use and Land Cover for the Study Subwatersheds

APPENDIX 1. Detailed Land Use and Land Cover for the Study Area Subwatersheds.

TABLE 1.1 Humbert Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
bare rock/sand/clay	0.20	0.08	0.00
deciduous forest	35.30	14.29	0.60
emergent herbaceous wetland	2.20	0.89	0.04
evergreen forest	0.10	0.04	0.00
grassland/herbaceous	34.40	13.93	0.59
high intensity residential	38.80	15.71	0.66
high intensity commercial/ind/trans	60.60	24.53	1.03
low intensity residential	120.30	48.70	2.05
open water	0.50	0.20	0.01
other grasses (urban,rec,parks)	45.80	18.54	0.78
pasture/hay	493.00	199.60	8.41
row crops	5022.00	2033.20	85.71
small grains	0.00	0.00	0.00
woody wetlands	6.20	2.51	0.11
TOTAL	**5859.40**	**2372.23**	**100%**

TABLE 1.2 Howarth Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
bare rock/sand/clay	0	0.00	0.00
deciduous forest	17.9	7.25	0.52
emergent herbaceous wetland	0.7	0.28	0.02
evergreen forest	0.9	0.36	0.03
grassland/herbaceous	13.1	5.30	0.38
high intensity residential	0.4	0.16	0.01
high intensity commercial/ind/trans	15.2	6.15	0.44
low intensity residential	4.8	1.94	0.14
open water	0	0.00	0.00
other grasses (urban,rec,parks)	2.5	1.01	0.07
pasture/hay	188.5	76.32	5.45
row crops	3208.6	1299.03	92.84
small grains	0	0.00	0.00
woody wetlands	3.5	1.42	0.10
TOTAL	**3456.10**	**1399.23**	**100%**

TABLE 1.3 Wattles Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
bare rock/sand/clay	0	0.00	0.00
deciduous forest	10.2	4.13	0.79
emergent herbaceous wetland	0.2	0.08	0.02
evergreen forest	1.6	0.65	0.12
grassland/herbaceous	0.9	0.36	0.07
high intensity residential	0	0.00	0.00
high intensity commercial/ind/trans	0	0.00	0.00
low intensity residential	0.7	0.28	0.05
open water	0	0.00	0.00
other grasses (urban,rec,parks)	0	0.00	0.00
pasture/hay	168.3	68.14	12.96
row crops	1116.8	452.15	85.97
small grains	0	0.00	0.00
woody wetlands	0.2	0.08	0.02
TOTAL	**1298.90**	**525.87**	**100%**

TABLE 1.4 Seamons Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
bare rock/sand/clay	0	0.00	0.00
deciduous forest	35.9	14.53	0.96
emergent herbaceous wetland	0	0.00	0.00
evergreen forest	3.2	1.30	0.09
grassland/herbaceous	26.1	10.57	0.70
high intensity residential	23.7	9.60	0.64
high intensity commercial/ind/trans	0	0.00	0.00
low intensity residential	0	0.00	0.00
open water	1.9	0.77	0.05
other grasses (urban,rec,parks)	0.2	0.08	0.01
pasture/hay	340.8	137.98	9.14
row crops	3285.2	1330.04	88.10
small grains	0.3	0.12	0.01
woody wetlands	11.4	4.62	0.31
TOTAL	**3728.70**	**1509.60**	**100%**

TABLE 1.5 Upper Mud Pine Creek Subwatershed.

landcover	area (acres)	area (ha)	%
bare rock/sand/clay	0	0.00	0.00
deciduous forest	15.9	6.44	0.53
emergent herbaceous wetland	0.2	0.08	0.01
evergreen forest	0	0.00	0.00
grassland/herbaceous	3.9	1.58	0.13
high intensity residential	0.3	0.12	0.01
high intensity commercial/ind/trans	0	0.00	0.00
low intensity residential	0.1	0.04	0.00
open water	0	0.00	0.00
other grasses (urban,rec,parks)	0	0.00	0.00
pasture/hay	252.6	102.27	8.36
row crops	2749.2	1113.04	90.94
small grains	0	0.00	0.00
woody wetlands	0.6	0.24	0.02
TOTAL	**3022.80**	**1223.81**	**100%**

TABLE 1.6 Volz Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
bare rock/sand/clay	0	0.00	0.00
deciduous forest	40.1	16.23	0.56
emergent herbaceous wetland	0.2	0.08	0.00
evergreen forest	4.4	1.78	0.06
grassland/herbaceous	21.8	8.83	0.31
high intensity residential	0	0.00	0.00
high intensity commercial/ind/trans	15.6	6.32	0.22
low intensity residential	0	0.00	0.00
open water	0	0.00	0.00
other grasses (urban,rec,parks)	0	0.00	0.00
pasture/hay	589.4	238.62	8.29
row crops	6432.8	2604.37	90.42
small grains	0	0.00	0.00
woody wetlands	9.5	3.85	0.13
TOTAL	**7113.80**	**2880.08**	**100%**

TABLE 1.7 Goose Creek Subwatershed.

landcover	area (acres)	area (ha)	%
bare rock/sand/clay	0.2	0.08	0.00
deciduous forest	53.6	21.70	0.60
emergent herbaceous wetland	1.9	0.77	0.02
evergreen forest	1.1	0.45	0.01
grassland/herbaceous	49.2	19.92	0.55
high intensity residential	29.8	12.06	0.33
high intensity commercial/ind/trans	61.1	24.74	0.68
low intensity residential	82.7	33.48	0.92
open water	2.4	0.97	0.03
other grasses (urban,rec,parks)	0.8	0.32	0.01
pasture/hay	878.1	355.51	9.78
row crops	7803.2	3159.19	86.94
small grains	0.4	0.16	0.00
woody wetlands	10.1	4.09	0.11
TOTAL	**8974.60**	**3633.44**	**100%**

TABLE 1.8 Lower Mud Pine Creek Subwatershed.

landcover	area (acres)	area (ha)	%
bare rock/sand/clay	0	0.00	0.00
deciduous forest	138.3	55.99	1.66
emergent herbaceous wetland	9.4	3.81	0.11
evergreen forest	19.6	7.94	0.23
grassland/herbaceous	50.1	20.28	0.60
high intensity residential	0	0.00	0.00
high intensity commercial/ind/trans	59.1	23.93	0.71
low intensity residential	12.3	4.98	0.15
open water	5	2.02	0.06
other grasses (urban,rec,parks)	5.3	2.15	0.06
pasture/hay	1116.7	452.11	13.39
row crops	6867.2	2780.24	82.33
small grains	0	0.00	0.00
woody wetlands	58.6	23.72	0.70
TOTAL	**8341.60**	**3377.17**	**100%**

APPENDIX 2:

Structural and Managerial Conservation Practices

APPENDIX 2. Structural and managerial conservation practices that are relevant for use in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. These conservation practices were adapted from the National Handbook of Conservation Practices. Their listing here does not imply endorsement by J.F. New & Associates, nor will every practice be relevant to every situation.

TABLE 2.1 Structural conservation practices that are relevant for use in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

Alley Cropping	Field Border	Sediment Basin
Access Road	Filter Strip	Stream Habitat Improvement and Management
Anionic Polyacrylamide (PAM) Erosion Control	Fish Passage	Streambank and Shoreline Protection
Animal Trails and Walkways	Floodwater Diversion	Structure for Water Control
Channel Vegetation	Floodway	Subsurface Drain
Clearing and Snagging	Grade Stabilization Structure	Surface Drainage, Field Ditch
Composting Facility	Grassed Waterway	Tree-Shrub Establishment
Conservation Cover	Grazing Land Mechanical Treatment	Tree/Shrub Pruning
Constructed Wetland	Heavy Use Area Protection	Underground Outlet
Contour Buffer Strips	Hedgerow Planting	Vegetative Buffers
Contour Farming	Herbaceous Wind Barriers	Waste Storage Facility
Controlled Drainage	Land Clearing	Waste Treatment Lagoon
Cover Crop	Lined Waterway or Outlet	Water and Sediment Control Basin
Critical Area Planting	Obstruction Removal	Water Table Control
Dam, Diversion	Open Channel	Wetland Creation
Dam, Floodwater Retarding	Pond	Wetland Enhancement
Dam, Mulitple Purpose	Range Planting	Wetland Restoration
Dike	Riparian Forest Buffer	Wildlife Watering Facility
Diversion	Riparian Herbaceous Cover	Windbreak/Shelterbelt Establishment
Fence	Rock Barrier	Windbreak/Shelterbelt Renovation

Source: National Handbook of Conservation Practices: **http://www.ncg.nrcs.usda.gov/nhcp_2.html**. Practice standards are available online at the above website or by contacting your county NRCS office.

TABLE 2.2 Managerial conservation practices that are relevant for use in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

Bedding	Nutrient Management	Roof Runoff Management
Brush Management	Pasture and Hay Planting	Row Arrangement
Conservation Crop Rotation	Pest Management	Runoff Management System
Deep Tillage	Prescribed Burning	Shallow Water Management for Wildlife
Early Successional Habitat Development/Management	Prescribed Grazing	Stream Habitat Improvement and Management
Fishpond Management	Residue Management, Mulch Till	Stripcropping
Forage Harvest Management	Residue Management, No-Till and Strip Till	Upland Wildlife Habitat
Irrigation Water Management	Residue Management, Ridge Till	Waste Utilization
Manure Transfer	Residue Management, Seasonal	Water Table Control
Mulching	Restoration and Management of Declining Habitats	Wetland Wildlife Habitat Management

Source: National Handbook of Conservation Practices: **http://www.ncg.nrcs.usda.gov/nhcp_2.html**. Practice standards are available online at the above website or by contacting your county NRCS office.

APPENDIX 3:

Photos from the Riparian Management System Model in the Bear Creek Watershed, Iowa (Isenhart et al., 1997)

Bear Creek riparian management site from the Isenhart et al., 1997 study. Top photo shows site in March 1990, prior to buffer strip establishment. The bottom photo shows the same site in June 1994 after five growing seasons. Used with permission from the American Fisheries Society.

Wetland component of the Bear Creek riparian management system model from the Isenhart et al., 1997 study. Photo was taken in August 1994, a few months after construction. The water control structure can be seen in the foreground. Used with permission from the American Fisheries Society.

APPENDIX 4:

Endangered, Threatened, and Rare Species List, Upper Mud Pine Creek Watershed

March 8, 2001

ENDANGERED, THREATENED, AND RARE SPECIES
AND HIGH QUALITY NATURAL COMMUNITIES AND NATURAL AREAS DOCUMENTED FROM
THE MUD CREEK WATERSHED, BENTON AND ~~WARREN~~ COUNTIES, INDIANA

Type.........	Element Name................	Common Name...............	State	Fed..	Townrang Sec	....	Date	Comments
FOWLER QUADRANGLE								
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	024N008W 28	NEQ NEQ NEQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	025N008W 25 025N008W 31	NWQ SEQ SEQ	1988	
Mammal	MUSTELA NIVALIS	LEAST WEASEL	SSC	**	025N007W 31	NWQ NWQ	1988	
Mammal	SPERMOPHILUS FRANKLINII	FRANKLIN'S GROUND SQUIRREL	SE	**	024N007W 08 025N007W 31 025N007W 25	NEQ SEQ SEQ	1994	
Mammal	SPERMOPHILUS FRANKLINII	FRANKLIN'S GROUND SQUIRREL	SE	**	024N007W 08 025N007W 31 025N007W 25	NEQ SEQ SEQ	1994	
Bird	ASIO FLAMMEUS	SHORT-EARED OWL	SE	**	025N008W 30		1988	
Bird	STURNELLA NEGLECTA	WESTERN MEADOWLARK	SSC	**	024N008W 30		1997	
Plant	AGALINIS AURICULATA	EARLEAF FOXGLOVE	SE	**		APPROX 1 MI S-SW OF FOWLER.	1930	
Plant	GENTIANA PUBERULENTA	DOWNY GENTIAN	ST	**	025N008W	FOWLER	NO D	
Plant	PRENANTHES ASPERA	ROUGH RATTLESNAKE-ROOT	SR	**	025N008W 16	SEQ SEQ	1928	
FOWLER RAILROAD PRAIRIE SITE								
Mammal	SPERMOPHILUS FRANKLINII	FRANKLIN'S GROUND SQUIRREL	SE	**	025N008W 23 025N008W 26	 NEQ	1987	
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	025N008W 23	SEQ SEQ SEQ	1988	
Reptile	LIOCHLOROPHIS VERNALIS	SMOOTH GREEN SNAKE	SE	**	025N008W 23	NWQ SEQ	1988	
High Quality Community	PRAIRIE - MESIC	MESIC PRAIRIE	SG	**	025N008W		NO D	
Plant	LIATRIS PYCNOSTACHYA	CATTAIL GAY-FEATHER	ST	**	025N008W 26 025N008W 23	NEQ SEQ	1981	
PINE VILLAGE QUADRANGLE								
Fish	ETHEOSTOMA CAMURUM	BLUEBREAST DARTER	SE	**	~~023N008W~~ 29	NWQ SEQ NEQ	1998	
Fish	ETHEOSTOMA CAMURUM	BLUEBREAST DARTER	SE	**	024N008W 32		1998	
Fish	ETHEOSTOMA CAMURUM	BLUEBREAST DARTER	SE	**	~~023N008W~~ 17	WH WH	1998	
Plant	ARENARIA PATULA	PITCHER'S STITCHWORT	SE	**	~~023N0008~~ 03		1919	
Plant	ASTER FURCATUS	FORKED ASTER	SR	**	~~023N008W~~ 33	NEQ NWQ	1992	
Plant	CRATAEGUS PEDICELLATA	SCARLET HAWTHORN	ST	**	~~023N008W~~ 28		1919	
Plant	SAXIFRAGA FORBESII	FORBES SAXIFRAGE	SE	**	~~023N008W~~ 33	CENTER	1983	
Plant	SELAGINELLA RUPESTRIS	LEDGE SPIKE-MOSS	ST	**	~~023N008W~~ 33	NEQ NWQ NWQ	1998	
MUD PINE CREEK-TILL HILL PRAIRIE SITE								
High Quality Community	PRAIRIE - DRY-MESIC	DRY-MESIC PRAIRIE	SG	**	~~023N008W~~ 28	EXTREME SWQ	1981	
Plant	ASTER SERICEUS	WESTERN SILVERY ASTER	SR	**	~~023N008W~~ 29	SEQ SEQ	1998	
RAINSVILLE SITE								
Plant	SELAGINELLA RUPESTRIS	LEDGE SPIKE-MOSS	ST	**	~~023N008W~~ 33	SWQ NEQ	1980	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant, SRE=state reintroduced

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 5:

Endangered, Threatened, and Rare Species List,
Benton County

November 16, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM BENTON COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
AGALINIS AURICULATA	EARLEAF FOXGLOVE	SE	**	S1	G3
ASTER SERICEUS	WESTERN SILVERY ASTER	SR	**	S2	G5
CAMASSIA ANGUSTA	WILD HYACINTH	SE	**	S1	G5?Q
CAREX GRAVIDA	HEAVY SEDGE	SE	**	S1	G5
CIRSIUM HILLII	HILL'S THISTLE	SE	**	S1	G3
GENTIANA PUBERULENTA	DOWNY GENTIAN	ST	**	S2	G4G5
LIATRIS PYCNOSTACHYA	CATTAIL GAY-FEATHER	ST	**	S2	G5
PANICUM LEIBERGII	LEIBERG'S WITCHGRASS	ST	**	S2	G5
PRENANTHES ASPERA	ROUGH RATTLESNAKE-ROOT	SR	**	S2	G4?
VIOLA PEDATIFIDA	PRAIRIE VIOLET	ST	**	S2	G5
FISH					
ETHEOSTOMA VARIATUM	VARIEGATE DARTER	SE	**	S1	G5
REPTILES					
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
LIOCHLOROPHIS VERNALIS	SMOOTH GREEN SNAKE	SE	**	S2	G5
BIRDS					
ASIO FLAMMEUS	SHORT-EARED OWL	SE	**	S2	G5
BARTRAMIA LONGICAUDA	UPLAND SANDPIPER	SE	**	S3B	G5
CIRCUS CYANEUS	NORTHERN HARRIER	SE	**	S2	G5
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
RALLUS ELEGANS	KING RAIL	SE	**	S1B,SZN	G4G5
TYTO ALBA	BARN OWL	SE	**	S2	G5
MAMMALS					
GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	S2	G5
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
REITHRODONTOMYS MEGALOTIS	WESTERN HARVEST MOUSE	SSC	**	S2	G5
SPERMOPHILUS FRANKLINII	FRANKLIN'S GROUND SQUIRREL	SE	**	S2	G5
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
PRAIRIE - MESIC	MESIC PRAIRIE	SG	**	S2	G2
OTHER FEATURE OF SIGNIFICANCE					
MIGRATORY BIRD CONCENTRATION SITE	MIGRATORY BIRD CONCENTRATION SITE	SG	**		

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 6:

Stream Sampling Laboratory Datasheets

Report of Laboratory Analysis

ENVIRONMENTAL LABORATORIES, INC.

ENVIRONMENTAL LABORATORIES, INC.
635 Green Rd., P.O. Box 968 • Madison, IN 47250
Lab: (812) 273-6699

Reported To:
CORNELIA SAWATZKY
J.F. NEW & ASSOCIATES
708 ROOSEVELT RD.

WALKERTON, IN 46574

Order No.: 2001050577
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 1
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 1

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
NITRITE+NITRATE-N	0.9	mg/L	CM	0.0100	18-4500-NO3-	06/01/2001

Sample No.: 2
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 1

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
pH	6.80	S.U.	DL	0.1000	18-4500-H+-B	05/18/2001
SOLIDS, SUSPENDED TOTAL	9.00	mg/L	DL	1.0000	18-2540-D	05/25/2001
TURBIDITY	1.000	NTU	CM	1.0000	EPA-180.1	05/28/2001
CONDUCTIVITY	310.0	µmhos/cm	DL	1.0000	18-2510-B	06/01/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

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708 ROOSEVELT RD.

WALKERTON, IN 46574

Order No.: 2001050577
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 3
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 1

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHATE,TOTAL-(As "P")	0.511	mg/L	CM	0.0050	Hach 8190	06/11/2001
AMMONIA-N	0.80	mg/L	CM	0.1000	18-4500-NH3-	06/04/2001
TKN	2.3000	mg/L	CM	1.0000	18-4500-N-B	06/11/2001

Sample No.: 4
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 1

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHATE, ORTHO	0.0160	mg/L	CM	0.0050	Hach 8190	06/11/2001

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 1

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis

Approved By: Chris E. Myers

Report of Laboratory Analysis

ENVIRONMENTAL LABORATORIES, INC.

ENVIRONMENTAL LABORATORIES, INC.
635 Green Rd., P.O. Box 968 • Madison, IN 47250
Lab: (812) 273-6699

Reported To:
CORNELIA SAWATZKY
J.F. NEW & ASSOCIATES
708 ROOSEVELT RD.

WALKERTON, IN 46574

Order No.: 2001050577
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.

Comments:

Matrix: Other

Location: SITE 1

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
E-COLI, MEMBRANE FILTR.	250.000000	cfu/100ML	CM	1.0000	18-9213-D	05/19/2001

Approved By: Chris E. Myers

Report of
Laboratory
Analysis

ENVIRONMENTAL LABORATORIES, INC.

ENVIRONMENTAL LABORATORIES, INC.
635 Green Rd., P.O. Box 968 • Madison, IN 47250
Lab: (812) 273-6699

Reported To:
CORNELIA SAWATZKY
J.F. NEW & ASSOCIATES
708 ROOSEVELT RD.

WALKERTON, IN 46574

Order No.: 2001050578
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 1
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 2

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
NITRITE+NITRATE-N	0.9	mg/L	CM	0.0100	18-4500-NO3-	06/01/2001

Sample No.: 2
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 2

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
pH	6.80	S.U.	DL	0.1000	18-4500-H+-B	05/18/2001
TURBIDITY	<1.0000	NTU	CM	1.0000	EPA-180.1	05/28/2001
SOLIDS, SUSPENDED TOTAL	8.00	mg/L	DL	1.0000	18-2540-D	05/25/2001
CONDUCTIVITY	400.0	µmhos/cm	DL	1.0000	18-2510-B	06/11/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

ENVIRONMENTAL LABORATORIES, INC.

ENVIRONMENTAL LABORATORIES, INC.
635 Green Rd., P.O. Box 968 • Madison, IN 47250
Lab: (812) 273-6699

Reported To:
CORNELIA SAWATZKY
J.F. NEW & ASSOCIATES
708 ROOSEVELT RD.

WALKERTON, IN 46574

Order No.: 2001050578
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 3
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 2

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHORUS, TOTAL	0.4150	mg/L	CM	0.0050	Hach 8190	06/11/2001
AMMONIA-N	0.80	mg/L	CM	0.1000	18-4500-NH3-	06/04/2001
TKN	2.2000	mg/L	CM	1.0000	18-4500-N-B	06/11/2001

Sample No.: 4
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 2

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHATE, ORTHO	0.0140	mg/L	CM	0.0050	Hach 8190	06/11/2001

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.
Comments:
Matrix: Other
Location: SITE 2

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis

Approved By: Chris E. Myers

Report of Laboratory Analysis

ENVIRONMENTAL LABORATORIES, INC.

ENVIRONMENTAL LABORATORIES, INC.
635 Green Rd., P.O. Box 968 • Madison, IN 47250
Lab: (812) 273-6699

Reported To:
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J.F. NEW & ASSOCIATES
708 ROOSEVELT RD.

WALKERTON, IN 46574

Order No.: 2001050578
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. , M.G.

Comments:

Matrix: Other

Location: SITE 2

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
E-COLI, MEMBRANE FILTR.	200.000000	cfu/100ML	CM	1.0000	18-9213-D	05/19/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

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WALKERTON, IN 46574

Order No.: 2001050579
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 1
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 3

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
NITRITE+NITRATE-N	1.0	mg/L	CM	0.0100	18-4500-NO3-	06/01/2001

Sample No.: 2
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 3

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
pH	6.90	S.U.	DL	0.1000	18-4500-H+-B	05/18/2001
SOLIDS, SUSPENDED TOTAL	6.00	mg/L	DL	1.0000	18-2540-D	05/25/2001
TURBIDITY	2.000	NTU	CM	1.0000	EPA-180.1	05/28/2001
CONDUCTIVITY	360.0	µmhos/cm	DL	1.0000	18-2510-B	06/01/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

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WALKERTON, IN 46574

Order No.: 2001050579
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 3
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 3

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHORUS, TOTAL	0.520	mg/L	CM	0.0050	Hach 8190	06/11/2001
AMMONIA-N	0.90	mg/L	CM	0.1000	18-4500-NH3-	06/04/2001
TKN	2.6000	mg/L	CM	1.0000	18-4500-N-B	06/11/2001

Sample No.: 4
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 3

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHATE, ORTHO	0.0150	mg/L	CM	0.0050	Hach 8190	06/11/2001

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 3

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis

Approved By: Chris E. Myers

Report of
Laboratory
Analysis

ENVIRONMENTAL LABORATORIES, INC.

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Reported To:
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WALKERTON, IN 46574

Order No.: **2001050579**
P.O. No.:
Date Received: **05/18/2001**
Report Date: **06/12/2001**

Testing Analysis

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.

Comments:

Matrix: Other

Location: SITE 3

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
E-COLI, MEMBRANE FILTR.	220.000000	cfu/100ML	CM	1.0000	18-9213-D	05/19/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

ENVIRONMENTAL LABORATORIES, INC.

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Reported To:
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WALKERTON, IN 46574

Order No.: 2001050580
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 1
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. M.G.
Comments:
Matrix: Other
Location: SITE 4

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
NITRITE+NITRATE-N	1.0	mg/L	CM	0.0100	18-4500-NO3-	06/01/2001

Sample No.: 2
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. M.G.
Comments:
Matrix: Other
Location: SITE 4

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
pH	6.90	S.U.	DL	0.1000	18-4500-H+-B	05/18/2001
SOLIDS, SUSPENDED TOTAL	8.00	mg/L	DL	1.0000	18-2540-D	05/25/2001
TURBIDITY	1.000	NTU	CM	1.0000	EPA-180.1	05/28/2001
CONDUCTIVITY	320.0	µmhos/cm	DL	1.0000	18-2510-B	06/01/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

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Order No.: 2001050580
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 3
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. M.G.
Comments:
Location: SITE 4
Matrix: Other

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHORUS, TOTAL	0.4650	mg/L	CM	0.0050	Hach 8190	06/11/2001
AMMONIA-N	0.80	mg/L	CM	0.1000	18-4500-NH3-	06/04/2001
TKN	2.3000	mg/L	CM	1.0000	18-4500-N-B	06/11/2001

Sample No.: 4
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. M.G.
Comments:
Location: SITE 4
Matrix: Other

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHATE, ORTHO	0.0130	mg/L	CM	0.0050	Hach 8190	06/11/2001

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. M.G.
Comments:
Location: SITE 4
Matrix: Other

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis

Approved By: Chris E. Myers

Report of Laboratory Analysis

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WALKERTON, IN 46574

Order No.: 2001050580
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z. M.G.

Comments:

Matrix: Other

Location: SITE 4

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
E-COLI, MEMBRANE FILTR.	300.000000	cfu/100ML	CM	1.0000	18-9213-D	05/19/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

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WALKERTON, IN 46574

Order No.: 2001050581
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 1
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 5

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
NITRITE+NITRATE-N	0.44	mg/L	CM	0.0100	18-4500-NO3-	06/01/2001

Sample No.: 2
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 5

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
pH	6.80	S.U.	DL	0.1000	18-4500-H+-B	05/18/2001
SOLIDS, SUSPENDED TOTAL	9.00	mg/L	DL	1.0000	18-2540-D	05/25/2001
TURBIDITY	<1.0000	NTU	CM	1.0000	EPA-180.1	05/28/2001
CONDUCTIVITY	220.0	µmhos/cm	DL	1.0000	18-2510-B	06/01/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

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Lab: (812) 273-6699

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J.F. NEW & ASSOCIATES
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WALKERTON, IN 46574

Order No.: 2001050581
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 3
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 5

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHORUS, TOTAL	0.4600	mg/L	CM	0.0050	Hach 8190	06/11/2001
AMMONIA-N	0.60	mg/L	CM	0.1000	18-4500-NH3-	06/04/2001
TKN	1.9000	mg/L	CM	1.0000	18-4500-N-B	06/11/2001

Sample No.: 4
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 5

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHATE, ORTHO	0.0110	mg/L	CM	0.0050	Hach 8190	06/11/2001

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 5

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis

Approved By: Chris E. Myers

Report of
Laboratory
Analysis

ENVIRONMENTAL LABORATORIES, INC.

ENVIRONMENTAL LABORATORIES, INC.
635 Green Rd., P.O. Box 968 • Madison, IN 47250
Lab: (812) 273-6699

Reported To:
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J.F. NEW & ASSOCIATES
708 ROOSEVELT RD.

WALKERTON, IN 46574

Order No.: 2001050581
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.

Comments:

Matrix: Other

Location: SITE 5

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
E-COLI, MEMBRANE FILTR.	330.000000	cfu/100ML	CM	1.0000	18-9213-D	05/19/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

ENVIRONMENTAL LABORATORIES, INC.

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Lab: (812) 273-6699

Reported To:
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Order No.: 2001050582
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 1
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 6

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
NITRITE+NITRATE-N	0.36	mg/L	CM	0.0100	18-4500-NO3-	06/01/2001

Sample No.: 2
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 6

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
pH	6.90	S.U.	DL	0.1000	18-4500-H+-B	05/18/2001
SOLIDS, SUSPENDED TOTAL	7.00	mg/L	DL	1.0000	18-2540-D	05/25/2001
TURBIDITY	5.000	NTU	CM	1.0000	EPA-180.1	05/28/2001
CONDUCTIVITY	360.0	µmhos/cm	DL	1.0000	18-2510-B	06/01/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

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Order No.: 2001050582
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 1
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 6

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
NITRITE+NITRATE-N	0.36	mg/L	CM	0.0100	18-4500-NO3-	06/01/2001

Sample No.: 2
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 6

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
pH	6.90	S.U.	DL	0.1000	18-4500-H+-B	05/18/2001
SOLIDS, SUSPENDED TOTAL	7.00	mg/L	DL	1.0000	18-2540-D	05/25/2001
TURBIDITY	5.000	NTU	CM	1.0000	EPA-180.1	05/28/2001
CONDUCTIVITY	360.0	µmhos/cm	DL	1.0000	18-2510-B	06/01/2001

Approved By: Chris E. Myers

Report of
Laboratory
Analysis

ENVIRONMENTAL LABORATORIES, INC.

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635 Green Rd., P.O. Box 968 • Madison, IN 47250
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WALKERTON, IN 46574

Order No.: 2001050582
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.

Comments:

Matrix: Other

Location: SITE 6

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
E-COLI, MEMBRANE FILTR.	300.000000	cfu/100ML	CM	1.0000	18-9213-D	05/19/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

ENVIRONMENTAL LABORATORIES, INC.

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635 Green Rd., P.O. Box 968 • Madison, IN 47250
Lab: (812) 273-6699

Reported To:
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J.F. NEW & ASSOCIATES
708 ROOSEVELT RD.

WALKERTON, IN 46574

Order No.: 2001050583
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 1
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.

Comments:

Location: SITE 7

Matrix: Other

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
NITRITE+NITRATE-N	1.0	mg/L	CM	0.0100	18-4500-NO3-	06/01/2001

Sample No.: 2
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.

Comments:

Location: SITE 7

Matrix: Other

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
pH	6.90	S.U.	DL	0.1000	18-4500-H+-B	05/18/2001
SOLIDS, SUSPENDED TOTAL	8.00	mg/L	DL	1.0000	18-2540-D	05/25/2001
TURBIDITY	8.000	NTU	CM	1.0000	EPA-180.1	05/28/2001
CONDUCTIVITY	420.0	µmhos/cm	DL	1.0000	18-2510-B	06/01/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

ENVIRONMENTAL LABORATORIES, INC.

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Lab: (812) 273-6699

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WALKERTON, IN 46574

Order No.: 2001050583
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 3
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Location: SITE 7
Matrix: Other

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHORUS, TOTAL	0.3950.	mg/L	CM	0.0050	Hach 8190	06/11/2001
AMMONIA-N	1.00	mg/L	CM	0.1000	18-4500-NH3-	06/04/2001
TKN	2.5000	mg/L	CM	1.0000	18-4500-N-B	06/11/2001

Sample No.: 4
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Location: SITE 7
Matrix: Other

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHATE, ORTHO	0.0120	mg/L	CM	0.0050	Hach 8190	06/11/2001

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Location: SITE 7
Matrix: Other

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis

Approved By: Chris E. Myers

Report of Laboratory Analysis

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Reported To:
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Order No.: 2001050583
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.

Comments:

Matrix: Other

Location: SITE 7

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
E-COLI, MEMBRANE FILTR.	220.000000	cfu/100ML	CM	1.0000	18-9213-D	05/19/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

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Reported To:
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WALKERTON, IN 46574

Order No.: 2001050584
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 1
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 8

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
NITRITE+NITRATE-N	0.30	mg/L	CM	0.0100	18-4500-NO3-	06/01/2001

Sample No.: 2
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 8

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
pH	6.80	S.U.	DL	0.1000	18-4500-H+-B	05/18/2001
SOLIDS, SUSPENDED TOTAL	7.00	mg/L	DL	1.0000	18-2540-D	05/25/2001
TURBIDITY	16.00	NTU	CM	1.0000	EPA-180.1	05/28/2001
CONDUCTIVITY	400.0	µmhos/cm	DL	1.0000	18-2510-B	06/01/2001

Approved By: Chris E. Myers

Report of Laboratory Analysis

ENVIRONMENTAL LABORATORIES, INC.

ENVIRONMENTAL LABORATORIES, INC.
635 Green Rd., P.O. Box 968 • Madison, IN 47250
Lab: (812) 273-6699

Reported To:
CORNELIA SAWATZKY
J.F. NEW & ASSOCIATES
708 ROOSEVELT RD.

WALKERTON, IN 46574

Order No.: 2001050584
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 3
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 8

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHORUS, TOTAL	0.3900	mg/L	CM	0.0050	Hach 8190	06/11/2001
AMMONIA-N	0.90	mg/L	CM	0.1000	18-4500-NH3-	06/04/2001
TKN	2.3000	mg/L	CM	1.0000	18-4500-N-B	06/11/2001

Sample No.: 4
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 8

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
PHOSPHATE, ORTHO	0.0110	mg/L	CM	0.0050	Hach 8190	06/11/2001

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.
Comments:
Matrix: Other
Location: SITE 8

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis

Approved By: Chris E. Myers

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Order No.: 2001050584
P.O. No.:
Date Received: 05/18/2001
Report Date: 06/12/2001

Testing Analysis

Sample No.: 5
Date Received: 05/18/2001
Date Collected: 05/18/2001
Collected by: S.Z., M.G.

Comments:

Matrix: Other

Location: SITE 8

Laboratory Test	Tested Value	Test Units	Test Analyst	Detection Limit	Test Method	Date of Analysis
E-COLI, MEMBRANE FILTR.	260.000000	cfu/100ML	CM	1.0000	18-9213-D	05/19/2001

Approved By: Chris E. Myers

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates PROJECT: ECOLI ATTN: Cornelia Sawatzkly

Customer Sample ID: 1
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-1
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	190	2	CFU/100 mL	06/26/01	kab

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates   PROJECT: ECOLI   ATTN: Cornelia Sawatzkly

Customer Sample ID: 2
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-2
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	70	2	CFU/100 mL	06/26/01	kab

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates PROJECT: ECOLI ATTN: Cornelia Sawatzkly

Customer Sample ID: 3
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-3
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	310	10	CFU/100 mL	06/26/01	kab

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates

PROJECT: ECOLI

ATTN: Cornelia Sawatzkly

Customer Sample ID: 4
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-4
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	280	2	CFU/100 mL	06/26/01	kab

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates   PROJECT: ECOLI   ATTN: Cornelia Sawatzkly

Customer Sample ID: 4 DUP
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-5
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	320	2	CFU/100 mL	06/26/01	kab

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates PROJECT: ECOLI ATTN: Cornelia Sawatzkly

Customer Sample ID: 5
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-6
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	240	2	CFU/100 mL	06/26/01	kab

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates

PROJECT: ECOLI

ATTN: Cornelia Sawatzkly

Customer Sample ID: 6
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-7
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	220	10	CFU/100 mL	06/26/01	kab

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates PROJECT: ECOLI ATTN: Cornelia Sawatzkly

Customer Sample ID: 7
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-8
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	350	10	CFU/100 mL	06/26/01	kab

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates   PROJECT: ECOLI   ATTN: Cornelia Sawatzkly

Customer Sample ID: 8
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-9
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	240	2	CFU/100 mL	06/26/01	kab

SEVERN TRENT SERVICES

LABORATORY TEST RESULTS

Job Number: 606733

Date: 06/27/2001

CUSTOMER: J.F.New & Associates PROJECT: ECOLI ATTN: Cornelia Sawatzkly

Customer Sample ID: 9
Date Sampled......: 06/26/2001
Time Sampled......: 00:00
Sample Matrix.....: Water

Laboratory Sample ID: 606733-10
Date Received.......: 06/26/2001
Time Received.......: 17:00

TEST METHOD	PARAMETER/TEST DESCRIPTION	SAMPLE RESULT	REPORTING LIMIT	UNITS	DATE	TECH
COLISCAN MF	Escherichia coli	2	2	CFU/100 mL	06/26/01	kab

APPENDIX 7:

QHEI Datasheet

STREAM: ______ **RIVER MILE:** ______ **DATE:** ______ **QHEI SCORE** [ ]

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** [ ]

TYPE	POOL	RIFFLE	TYPE	POOL	RIFFLE
BLDER/SLAB(10)			GRAVEL(7)		
BOULDER(9)			SAND(6)		
COBBLE(8)			BEDROCK(5)		
HARDPAN(4)			DETRITUS(3)		
MUCK/SILT(2)			ARTIFIC(0)		

SUBSTRATE ORIGIN (all): LIMESTONE(1), TILLS(1), SANDSTONE(0), SHALE(-1), COAL FINES(-2), RIP/RAP(0), HARDPAN(0)

SILT COVER (one): SILT-HEAVY(-2), SILT-MOD(-1), SILT-NORM(0), SILT-FREE(1)

Extent of Embeddedness (check one): EXTENSIVE(-2), MODERATE(-1), LOW(0), NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: >4(2) <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: ______

2) INSTREAM COVER: **COVER SCORE** [ ]

TYPE (Check all that apply): UNDERCUT BANKS(1), OVERHANGING VEGETATION(1), SHALLOWS (IN SLOW WATER)(1), DEEP POOLS(2), ROOTWADS(1), BOULDERS(1), OXBOWS(1), AQUATIC MACROPHYTES(1), LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE): EXTENSIVE >75%(11), MODERATE 25-75%(7), SPARSE 5-25%(3), NEARLY ABSENT <5%(1)

COMMENTS: ______

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** [ ]

SINUOSITY: HIGH(4), MODERATE(3), LOW(2), NONE(1)

DEVELOPMENT: EXCELLENT(7), GOOD(5), FAIR(3), POOR(1)

CHANNELIZATION: NONE(6), RECOVERED(4), RECOVERING(3), RECENT OR NO RECOVERY(1)

STABILITY: HIGH(3), MODERATE(2), LOW(1)

MODIFICATION/OTHER: SNAGGING, RELOCATION, CANOPY REMOVAL, DREDGING, ONE SIDE CHANNEL MODIFICATION, IMPOUND, ISLAND, LEVEED, BANK SHAPING

COMMENTS: ______

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** [ ]

River Right Looking Downstream

RIPARIAN WIDTH (per bank) — L R (per bank): WIDE >150 ft.(4), MODERATE 30-150 ft.(3), NARROW 15-30 ft.(2), VERY NARROW 3-15 ft.(1), NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY — L R (most predominant per bank): FOREST, SWAMP(3), OPEN PASTURE/ROW CROP(0), RESID.,PARK,NEW FIELD(1), FENCED PASTURE(1); L R (per bank): URBAN OR INDUSTRIAL(0), SHRUB OR OLD FIELD(2), CONSERV. TILLAGE(1), MINING/CONSTRUCTION(0)

BANK EROSION — L R (per bank): NONE OR LITTLE(3), MODERATE(2), HEAVY OR SEVERE(1)

COMMENTS: ______

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** [ ]

MAX.DEPTH (Check 1): >4 ft.(6), 2.4-4 ft.(4), 1.2-2.4 ft.(2), <1.2 ft.(1), <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): POOL WIDTH>RIFFLE WIDTH(2), POOL WIDTH=RIFFLE WIDTH(1), POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): TORRENTIAL(-1), FAST(1), MODERATE(1), SLOW(1), EDDIES(1), INTERSTITIAL(-1), INTERMITTENT(-2)

COMMENTS: ______

RIFFLE SCORE [ ]

RIFFLE/RUN DEPTH: GENERALLY >4 in. MAX.>20 in.(4), GENERALLY >4 in. MAX.<20 in.(3), GENERALLY 2-4 in.(1), GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: STABLE (e.g., Cobble,Boulder)(2), MOD.STABLE (e.g., Pea Gravel)(1), UNSTABLE (Gravel, Sand)(0), NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: EXTENSIVE(-1), MODERATE(0), LOW(1), NONE(2), NO RIFFLE(0)

COMMENTS: ______

6) GRADIENT (FEET/MILE): ______ **% POOL** ______ **% RIFFLE** ______ **% RUN** ______ **GRADIENT SCORE** [ ]

APPENDIX 8:

Detailed mIBI Results

APPENDIX 8. Detailed mIBI Results

Site 1. Humbert Ditch:

TABLE 8.1 Site 1 multi-habitat macroinvertebrate results, July 25, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Dryopidae	1		5	5	0.88
Coleoptera	Elmidae	3		4	12	2.63
Coleoptera	Hydrophilidae	20		5	100	17.54
Diptera	Chironomidae	22		8	176	19.30
Diptera	Simulidae	3		6	18	2.63
Ephemeroptera	Caenidae	3	3	7		2.63
Gastropoda	Physidae	13		8	104	11.40
Hemiptera	Gerridae	1		5	5	0.88
Hemiptera	Veliidae	2			0	1.75
Odonata	Coenagrionidae	27		9	243	23.68
Odonata	Calopterygidae	1		5	5	0.88
Odonata	Gomphidae	2		1	2	1.75
Trichoptera	Hydropyschidae	16	16	4	64	14.04
		114	**19**		**6.554 HBI**	

TABLE A-8.2 Site 1 mIBI metrics, July 25, 2001.

		Metric Score
HBI	6.55	0
No. Taxa (family)	13	4
% Dominant Taxa	23.7	6
EPT Index	2	0
EPT Count	19	0
EPT Count/Total Count	0.17	2
EPT Abun./Chir. Abun.	0.86	0
Chironomid Count	22.00	4
mIBI Score		**2.0**

Site 2. Howarth Ditch:

TABLE A-8.3 Site 2 multi-habitat macroinvertebrate results, July 25, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Haustoriidae	2			0	2.00
Bivalvia	Sphaeriidae	3		8	24	3.00
Coleoptera	Dytiscidae	4			0	4.00
Coleoptera	Hydrophilidae	5		5	25	5.00
Diptera	Chironomidae	12		8	96	12.00
Ephemeroptera	Baetidae	6	6	4	24	6.00
Gastropoda	Physidae	21		8	168	21.00
Gastropoda	Planorbidae	11		7	77	11.00
Hemiptera	Corixidae	2		10	20	2.00
Hemiptera	Gerridae	1		5	5	1.00
Hirudinea	Glossiphoniidae	1			0	1.00
Odonata	Aeshnidae	2		3	6	2.00
Odonata	Coenagrionidae	27		9	243	27.00
Odonata	Gomphidae	1		9	9	1.00
Platyhelminthes	Turbellaria	2		1	2	2.00
		100	**6**		**7.516 HBI**	

TABLE A-8.4 Site 2 mIBI metrics, July 25, 2001.

		Metric Score
HBI	7.52	0
No. Taxa (family)	15	6
% Dominant Taxa	27.0	6
EPT Index	1	0
EPT Count	6	0
EPT Count/Total Count	0.06	0
EPT Abun./Chir. Abun.	0.50	0
Chironomid Count	12.00	6
mIBI Score		**2.3**

Site 3. Wattles Ditch:

TABLE A-8.5 Site 3 multi-habitat macroinvertebrate results, July 25, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Bivalvia	Sphaeriidae	7		8	56	6.42
Coleoptera	Dytiscidae	1			0	0.92
Coleoptera	Elmidae	5		4	20	4.59
Coleoptera	Haliplidae	2		7	14	1.83
Diptera	Chironomidae	9		8	72	8.26
Diptera	Simulidae	1		6	6	0.92
Diptera	Stratiomyidae	1			0	0.92
Ephemeroptera	Baetidae	11	11	4	44	10.09
Ephemeroptera	Caenidae	2	2	7	14	1.83
Ephemeroptera	Ephemeridae	1	1	4	4	0.92
Gastropoda	Physidae	16		8	128	14.68
Gastropoda	Planorbidae	6		7	42	5.50
Hemiptera	Corixidae	2		10	20	1.83
Hirudinea	Glossiphonidae	1			0	0.92
Isopoda	Asellidae	23		8	184	21.10
Lepidoptera	Pyralidae	1		5	5	0.92
Odonata	Coenagrionidae	19		9	171	17.43
Odonata	Gomphidae	1		1	1	0.92
		109	**14**		**7.368 HBI**	

TABLE A-8.6 Site 3 mIBI metrics, July 25, 2001.

		Metric Score
HBI	7.37	0
No. Taxa (family)	18	8
% Dominant Taxa	21.1	8
EPT Index	3	2
EPT Count	14	0
EPT Count/Total Count	0.13	0
EPT Abun./Chir. Abun.	1.56	2
Chironomid Count	9.00	8
mIBI Score		**3.5**

Site 4. Seamons Ditch:

TABLE A-8.7 Site 4 multi-habitat macroinvertebrate results, July 25, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Talintridae	11		8	88	10.28
Bivalvia	Sphaeriidae	2		8	16	1.87
Coleoptera	Circulionidae	1			0	0.93
Coleoptera	Elmidae	3		4	12	2.80
Coleoptera	Haliplidae	5		7	35	4.67
Coleoptera	Hydrophilidae	6		5	30	5.61
Diptera	Chironomidae	20		8	160	18.69
Ephemeroptera	Baetidae	1	1	4	4	0.93
Ephemeroptera	Caenidae	8	8	7	56	7.48
Gastropoda	Physidae	16		8	128	14.95
Gastropoda	Planorbidae	8		7	56	7.48
Hemiptera	Corixidae	5		10	50	4.67
Odonata	Coenagrionidae	21		9	189	19.63
		107	**9**		**7.77 HBI**	

TABLE A-8.8 Site 4 mIBI metrics, July 25, 2001.

		Metric Score
HBI	7.77	0
No. Taxa (family)	13	4
% Dominant Taxa	19.6	8
EPT Index	2	0
EPT Count	9	0
EPT Count/Total Count	0.08	0
EPT Abun./Chir. Abun.	0.45	0
Chironomid Count	20.00	4
mIBI Score		**2.0**

Site 5. Mud Pine Creek:

TABLE A-8.9 Site 5 multi-habitat macroinvertebrate results, July 25, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Haliplidae	1		7	7	0.88
Coleoptera	Hydrophilidae	12		5	60	10.53
Diptera	Chironomidae	27		8	216	23.68
Ephemeroptera	Baetidae	2	2	4	8	1.75
Ephemeroptera	Caenidae	14	14	7	98	12.28
Ephemeroptera	Heptageniidae	1	1	4	4	0.88
Gastropoda	Physidae	17		8	136	14.91
Gastropoda	Planorbidae	17		7	119	14.91
Hemiptera	Gerridae	1		5	5	0.88
Hirudinea	Glossiphoniidae	1			0	0.88
Isopoda	Asellidae	1		8	8	0.88
Odonata	Coenagrionidae	19		9	171	16.67
Trichoptera	Helicopsychidae	1	1	3	3	0.88
		114	**18**		**7.389 HBI**	

TABLE A-8.10 Site 5 mIBI metrics, July 25, 2001.

		Metric Score
HBI	7.39	0
No. Taxa (family)	13	4
% Dominant Taxa	23.7	6
EPT Index	4	4
EPT Count	18	0
EPT Count/Total Count	0.16	2
EPT Abun./Chir. Abun.	0.67	0
Chironomid Count	27.00	4
mIBI Score		**2.5**

Site 6. Volz Ditch:

TABLE A-8.11 Site 6 multi-habitat macroinvertebrate results, July 25, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Dytiscidae	1			0	0.87
Coleoptera	Elmidae	2		4	8	1.74
Coleoptera	Hydrophilidae	18		5	90	15.65
Diptera	Ceratoponidae	1		6	6	0.87
Diptera	Chironomidae	2		8	16	1.74
Diptera	Culcidae	1			0	0.87
Ephemeroptera	Caenidae	5	5	7	35	4.35
Gastropoda	Physidae	9		8	72	7.83
Gastropoda	UK	3			0	2.61
Hemiptera	Belostomatidae	1			0	0.87
Hemiptera	Corixidae	49		10	490	42.61
Hemiptera	Naucoridae	1			0	0.87
Odonata	Coenagrionidae	22		9	198	19.13
		115	**5**		**8.472 HBI**	

TABLE A-8.12 Site 6 mIBI metrics, July 25, 2001.

		Metric Score
HBI	8.47	0
No. Taxa (family)	13	4
% Dominant Taxa	42.6	2
EPT Index	1	0
EPT Count	5	0
EPT Count/Total Count	0.04	0
EPT Abun./Chir. Abun.	2.50	2
Chironomid Count	2.00	8
mIBI Score		**2.0**

Site 7. Goose Creek:

TABLE A-8.13 Site 7 multi-habitat macroinvertebrate results, July 25, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Haustoriidae	1			0	0.93
Bivalvia	Sphaeriidae	17		8	136	15.74
Coleoptera	Dytiscidae	1			0	0.93
Coleoptera	Elmidae	3		4	12	2.78
Coleoptera	Haliplidae	2		7	14	1.85
Diptera	Chironomidae	14		8	112	12.96
Gastropoda	Physidae	16		8	128	14.81
Gastropoda	Planorbidae	4		7	28	3.70
Hemiptera	Corixidae	22		10	220	20.37
Hirudinea	Erpobdellidae	3			0	2.78
Hirudinea	Glossiphoniidae	2			0	1.85
Odonata	Coenagrionidae	15		9	135	13.89
Platyhelminthes	Turbellaria	7		1		6.48
Nematamorpha	??	1				0.93
		108	**6**		**7.85 HBI**	

TABLE A-8.14 Site 7 mIBI metrics, July 25, 2001.

		Metric Score
HBI	7.85	0
No. Taxa (family)	14	4
% Dominant Taxa	20.4	8
EPT Index	1	0
EPT Count	6	0
EPT Count/Total Count	0.06	0
EPT Abun./Chir. Abun.	0.43	0
Chironomid Count	14.00	6
mIBI Score		**2.3**

Site 8. Mud Pine Creek:

TABLE A-8.15 Site 8 multi-habitat macroinvertebrate results, July 25, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Elmidae	16		4	64	15.84
Diptera	Tabanidae	1		6	6	0.99
Ephemeroptera	Baetidae	4	4	4	16	3.96
Ephemeroptera	Caenidae	4	4	7	28	3.96
Ephemeroptera	Heptageniidae	3	3	4	12	2.97
Ephemeroptera	Oligoneuriidae	22	22	2	44	21.78
Hemiptera	Gerridae	2		5	10	1.98
Hemiptera	Mesoveliidae	1			0	0.99
Hemiptera	Veliidae	5			0	4.95
Odonata	Aeshnidae	1		3	3	0.99
Odonata	Calopterygidae	1		5	5	0.99
Trichoptera	Hydropsychidae	24	24	4	96	23.76
Trichoptera	Philopotamidae	17	17	3	51	16.83
		101	**74**		**3.526 HBI**	

TABLE A-8.16 Site 8 mIBI metrics, July 25, 2001.

		Metric Score
HBI	3.53	8
No. Taxa (family)	13	4
% Dominant Taxa	23.8	6
EPT Index	6	6
EPT Count	74	4
EPT Count/Total Count	0.73	8
EPT Abun./Chir. Abun.	N/A	8
Chironomid Count	0.00	8
mIBI Score		**6.5**